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OPERATIONALLY RESPONSIVE SPACE (ORS) ARCHITECTURE FOR THE YEAR 2025

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13. ABSTRACT (maximum 200 words)

The Unites States' first space systems programs, to include launch, ground, and space segments and their associated infrastructure, were initially developed to meet the requirements of the strategic users. Since the 1991 Gulf War, there has been a growing dependence on the capabilities and support delivered by those programs to meet requirements of non-strategic users. The current National Security Space (NSS) architecture makes it rather difficult and challenging for all but critical strategic users to fully capitalize on the available assets. Timelines that were once adequate to deliver strategic capabilities are now not sufficient to allow a broader range of users to realize the benefit from using the available space systems. In addition, the non-strategic users run into challenges when they attempt to change the tasking requirements that would enable them to receive associated products / services that are useful and timely.

With the identified gaps in the current NSS environment, the Integrated Product Team (IPT), consisting of ten active duty military students, sought solutions to make space more "Operationally Responsive" to its customers by 2025. Due to limited time and assets, the IPT narrowed the focus of the project to the four Joint Publication (JP) 3-14 "Joint Doctrine for Space Operations" mission areas of Space Support, Space Control, Force Enhancement, and Force Application.

During this project, the IPT defined Operationally Responsive Space (ORS) from its perspective, developed the requirements to meet the identified NSS gaps, selected the final alternatives to satisfy those requirements, and suggested an implementation plan. While in the architecture process, the IPT conducted an in-depth evaluation of the original [61] alternatives based on Responsiveness, Risk, Capability, and Cost. After building a foundation for further analysis, a total of 16 alternatives were chosen for the final ORS architecture.

The IPT's leading alternative that provided the most responsiveness was to create a Single Space Agency. The other alternatives range from establishing joint ventures with other countries to developing hypersonic lift vehicles to transport troops and supplies. A detailed list of the "Sweet Sixteen" can be found in Appendix E.

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PREFACE

SS4051 is the second course of a two course sequence which comprises the capstone project for the Space Systems Operations program at NPS. SS3041, the initial course, teaches the students the architectural design process – from generating basic requirements through conceiving of and evaluating alternative solutions and ultimately selecting the preferred approach. During SS3041, the students are presented a project – derived from current challenging and relevant efforts in the National Security Space area – and their primary "deliverable" at the completion of the class is a set of requirements for the assigned architecture to satisfy.

For the FY2008 effort, Operationally Responsive Space (ORS) was selected as the topic of study. In SS3041, the students defined what ORS "should be," and described the characteristics and capabilities of an ORS architecture. In SS4051, the students took these definitions and capabilities and generated alternative approaches to satisfying them. This report describes the result of that effort.

For FY2008, there were two in-residence teams of 10 students, and a single distance-learning team of 7 students. While most of the in-residence students had no space-related experience other than their time in the Space Systems Program at NPS, the majority of the distance-learning students had worked in or were currently working in space-related jobs.

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I. FORWARD

The Operationally Responsive Space (ORS) Architecture Project was completed to fulfill the requirements of a combined series of courses, SS3041 Space Systems Operations I and SS4051 Space Systems Operations II, both elements of the Space Systems Operations degree curriculum at the Naval Postgraduate School in Monterey, California. “Team A” consisted of active duty personnel from the Navy, the Army and the Marine Corps. Operational experience of the group ranged from staff tours to combat deployments and the combined service time of the group totaled over 170 years. Only two of the ten members have had direct experience in the National Security Space Enterprise, one during a tour at Cheyenne Mountain Operations Center and the other as the Space Battle Lab Liaison officer to the Army’s Command General Staff College. However, all members have used products or services supplied by the current space architecture at one time or another. This project was completed using the knowledge acquired during the course of study and influenced by the team’s operational experience

During both SS3041 and SS4051, the team was purposely given little “strategic” guidance to allow for the application of original thought in analyzing a topic that is of current interest to the National Security Space (NSS) community and perhaps develop a viable solution to the challenge of providing applicable and useful space related capabilities across a wide spectrum of users.

This project incorporated or referenced many of the thoughts and ideas developed by other attempts to define and implement ORS. However, due to limited time and assets, the group narrowed the focus of the project to the four Joint Publication (JP) 3-14 “Joint Doctrine for Space Operations” mission areas of Space Support, Space Control, Force Enhancement and Force Application. The group acknowledges that there are many other considerations that would need to be addressed to truly integrate responsive space across the spectrum of users. Any opinions expressed in this paper are those of the members of “Team A” and do not necessarily reflect those of the Space Systems Academic Group, the Naval Postgraduate School, or the Department of Defense.

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II. INTRODUCTION

The ORS project was unconstrained by any doctrine or policy. The Integrated Program Team (IPT), also known as Team A, created a final ORS architecture by, first, developing an ORS definition and requirements for the year 2025, and second, developing alternatives to satisfy those requirements. According to Team A's perspective of ORS, it touches all aspects of space or space related capabilities. ORS is an end state, a target that will guide the NSS architecture investment decisions for the next 17 years.

During this project, Team A equated themselves to a Task Force or a consultation firm, organized to determine an architecture and suggest a possible implementation in the broadest sense. The team took the point of view that their "services" would no longer be required once the final decision was presented and the architecture implemented.

A. BACKGROUND ON CLASS PROJECT

The class project was conducted during two twelve-week courses at Naval Postgraduate School: SS3041 Space Systems Operations I and SS4051 Space Systems Operations II. The team used their operational experience and class knowledge to develop the final ORS architecture.

SS3041: Space Systems Operations I

During SS3041, the goal was to define ORS and develop the requirements for the ORS architecture to fulfill the gaps found in the current NSS architecture. The team was influenced by current space efforts but was given free reign for creativity and out-of-the-box thinking. Due to time constraints, the team narrowed the scope to only cover the JP 3-14 mission areas. This portion of the project was mainly focused on the "what."

SS4051: Space Systems Operations II

During SS4051, the goal was to develop the final ORS architecture. The team developed alternatives to meet the requirements and then evaluated the alternatives against four criteria. Once the evaluation phase was complete, the team selected and implemented the best solution for ORS. Team A kept all research to open source and unclassified resources due to time constraints and other obligations. This portion of the project was mainly focused on the "how."

B. WHY DO ORS?

The Unites States' first space system programs (launch, ground, space segments as well as infrastructure) were developed with the strategic user in mind. Since the 1991 Gulf War, there has been a growing reliance on the capabilities and support delivered by those programs by non-strategic users (the military, other governmental agencies, the Intelligence Community (IC), etc). The current NSS architecture is still highly vertically oriented and not optimally utilized by the wide range of customers. Timelines that were once adequate to deliver strategic capability are not appropriate to allow a broader range of users to input desired tasking and to receive associated products / services that are useful and that are delivered when needed.

For this paper, the approach, purpose and the products are similar to the Responsive Space Operations (RSO) study conducted in 2004 – 2005 by the National Security Space Office (NSSO). The project began by listing potential requirements for any needed space support product or service based on a forecast of the political and military environment for the year 2025. The purpose focused on determining, evaluating and implementing potential solutions for a national space architecture that meets those requirements in an adequate amount of time to make that product or service useful for its intended purposes. Team A attempted to evaluate a range of alternatives across JP 3-14 defined mission areas sought to change and or improve current capabilities where they may be adequate or to develop new capabilities where gaps exist. The products of this study are a list of recommended capabilities the NSS architecture will be able to provide in 2025 and a list of suggestions for implementing the architecture.

C. CURRENT & FUTURE NSS ENVIRONMENT

Today, NSS is unable to meet the demanding needs of the U.S. Armed Forces. Space systems are still stove-piped, leaving no support to the tactical and operational users. The acquisition process is lengthy (10 – 15 years) and uncoordinated among agencies and Department of Defense (DOD). Products from the space assets are highly classified and difficult for others to access due to poor user knowledge. There is no single entity that determines the tasking of space assets, creating confusion and poor organizational management. Current launch system architecture is unable to meet short-notice launches (less than 6 months in length). The current architecture is unable to replace a failed or neutralized satellite in a timely manner to be effective to its customers.

Before defining ORS, Team A forecasted what the strategic environment would be in 2025. By 2025:

- United States (U.S.) will have at least two near-peer military competitors
- Global terrorism will still be a major issue
- Numerous nations will have space capabilities rivaling the U.S.’s
- Global economic interdependency (borderless world) will exist
- Neutrality of space may be contested

In essence, space capabilities will continue to grow in importance on a global scale. The current NSS environment is unable to compete with these future challenges. In order for the U.S. to be more competitive in the space arena during the 2025 timeframe, space must be more responsive to all users.

D. TEAM A DEFINITION OF ORS

Team A defined ORS as:

> *An adaptive architecture of physical and organizational structures that delivers space capabilities and effects to the warfighters, the intelligence community, and Department of Defense users in sufficient time to benefit tactical, operational, and strategic requirements.*

The three customers of ORS are DOD users, IC, and the warfighters. Although other customers such as NASA and NOAA could benefit from this study, Team A chose to limit the scope of the project to defense organizations only. DOD includes DOD agencies, military departments, Combatant Commands (COCOM). DOD users are stationary users who are shore-based. IC is "all departments or agencies of a government that are concerned with intelligence activities, either in an oversight, managerial, support, or participatory role" (JP 1-02). IC includes organizations such as Defense Intelligence Agency (DIA), National Geospatial Agency (NGA), and National Reconnaissance Office (NRO). The unofficial term of warfighter is any deployed or moving member of U.S. Armed Forces whether it is at sea, on the battlefield, or in the air (i.e. the "trigger pullers").

The three utility categories are tactical, operational, and strategic. The term tactical means actions related to a "battlefield" or "neighborhood," usually smaller unit actions. The term operational refers to campaign level actions, actions related to an "Area of Operation," or sustaining efforts. Strategic efforts include national and multi-national objectives, including actions related to "National Security" and the Global War on Terrorism (GWOT).

The two parts to ORS are physical and organizational structures. Examples of physical structures include launch facilities, satellites, new technologies, etc… Examples of organizational structures include acquisitions, chain-of-command, international partnerships, space operations center, etc…

ORS will provide an end-to-end and top-to-bottom perspective that, when established, will respond appropriately across a broad range of time scales to changing situations and stated tasking. These time scales range from short-term pop-up crisis situations to long-term persistence. Although Team A sought to develop a broader capability base, there will always be strategic requirements for space capabilities. The team must be careful not to shift the focus of the NSS architecture too far towards the tactical user, but rather implement a balanced architecture. Further, Team A hopes to develop an architecture that has an organic capability to shift its focus when changing needs are required and thus eliminating the need for further ORS "Office" efforts. The bottom line is that ORS should be able to deliver the desired space

capability to the right customer at the right time. The right time depends on the user and the situation where the effect is required.

E. ORS REQUIREMENTS

The ORS requirements were divided into the four JP 3-14 space mission areas: space control, force enhancement, space support, and space force application. These requirements were based on deficiencies or gaps in today's NSS environment. Each mission area had its own set of requirements needed to satisfy the customers in 2025. See Appendix A for the list of the ORS requirements.

F. ORS ALTERNATIVES

The alternatives that were evaluated during the final selection phase were created to meet each mission area's requirements. Team A brainstormed a total of sixty-one alternatives that were later evaluated against the chosen criteria. There were at least two alternatives for each requirement. See Appendix B for the list of the original alternatives used during the evaluation phase.

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III. ARCHITECTURE PROCESS

In order to develop a final architecture, the team employed a process that was taught during SS3041. This process assisted the team in selecting the best solution to satisfy the gaps from the current space environment. Figure 1 depicts the architecture process that Team A used to develop its alternatives, and ultimately, the final architecture for ORS. The following sections describe each phase of the process.

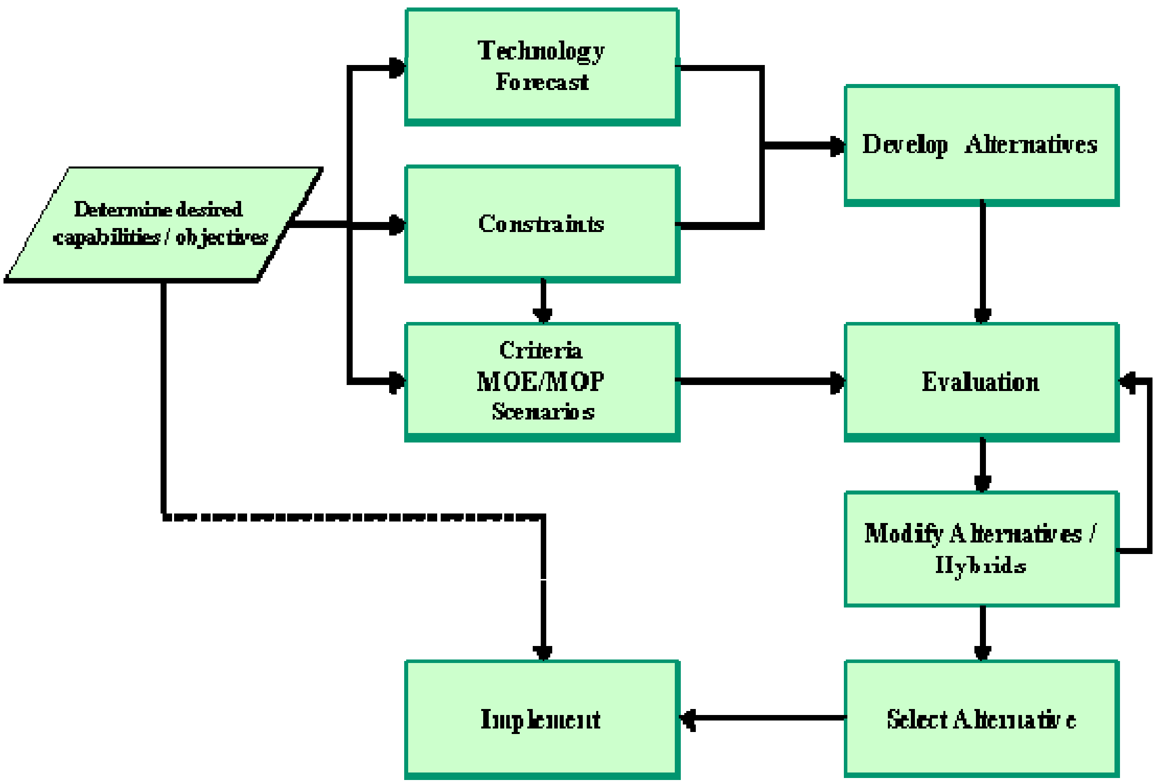

Figure 1: Architecture Process (SS 3041 Lecture Series 3b / Summer 2007)

A. DESIRED CAPABILITIES & OBJECTIVES

During the “Desired Capabilities & Objectives” phase, Team A defined ORS and developed a list of requirements that was used to fulfill the gaps in the current NSS environment. These requirements were developed in SS3041. Appendix A shows the list of the ORS

requirements developed by Team A. These requirements are based on Team A's perspective of ORS. During this phase, Team A answered the question: "what" is ORS?

B. TECHNOLOGY FORECAST

During the "Technology Forecast" phase, Team A answered the following questions according to each mission area:

- What technologies will or will not be mature by 2025?
- What technologies are well-proven today?

The goal of this phase was to address any technologies that will not be available by 2025 and remove those suggested alternatives early on during the process, saving time to discuss more important issues. Those long-term requirements developed in the first phase may be highly contested during the technology forecast segment.

C. CONSTRAINTS / RESTRAINTS

Team A considered possible constraints and restraints that could pose possible setbacks or challenges to the future ORS architecture. A constraint is a "must do" activity such as obeying international laws or going through the acquisition process. A restraint is a "can't do" activity such as the inability to defy the laws of gravity or the inability to spend more than what is budgeted. Most of the constraints / restraints were applicable across the board of the mission areas. Only some of these constraints are universal to all four mission areas. Below is a list of the possible constraints and restraints that Team A developed during this segment.

- Finite resources (time and money)
- Applicability to all levels of utility to all customers
- Technology
- Loss of technological superiority
- Acquisition process
- Interfaces / Interoperability
- International Treaties / Political ramifications of actions
- Current Policy / Law / Doctrine / Regulations

- Physics (orbital mechanics, Raleigh criteria, etc…)
- Space environment (solar weather, space junk, etc…)
- Launch hazards associated with populated areas or restricted air space

D. CRITERIA

During the "Criteria" phase, Team A discussed potential factors that would assist in evaluating the initial set of alternatives. The four criteria selected for the evaluation phase are 1) Responsiveness, 2) Cost, 3) Risk, and 4) Capability. The team was able to create a quantitative score for each alternative. These four factors will be discussed in great depth in the Method of Evaluation (MOE) chapter.

E. DEVELOP ALTERNATIVES

During the "Develop Alternatives" phase, each mission area compiled a list of potential alternatives that met the requirements developed in the first phase. After developing at least two alternatives for each requirement per mission area, Team A came up with the original sixty-one alternatives. See Appendix B for the original list of alternatives. During this phase, Team A answered the question: "how" will ORS be achieved?

F. EVALUATION

During the "Evaluation" phase, Team A evaluated all sixty-one alternatives against the four criteria selected in an earlier phase. The evaluation phase allowed Team A to assess a list of alternatives ranked from top to bottom. The outcome of this phase was to choose the top alternative from each sub-mission area, a total of fourteen alternatives, in order to include all aspects of space into the final ORS architecture. This provided a foundation for the team to conduct additional trade-off analysis. The MOE will be discussed in depth in the next chapter.

G. SELECT & MODIFY ALTERNATIVES FOR FINAL ARCHITECTURE

After further discussions with trade-offs and constraints, Team A selected and / or modified a total of sixteen alternatives for the final ORS architecture. These final sixteen alternatives are shown in Appendix E. Team A did not consider current space capabilities in the final ORS architecture because they assumed some portions of the current architecture will remain in position until replaced by a new, already-planned architecture or until end of life (i.e. ICBM, GPS, AEHF, TACSAT, etc…). Some of these alternatives resulted in a combination or a hybrid of numerous alternatives. At least one alternative was chosen for each sub-mission area. The goal was to get the "biggest bang for the buck." Team A underwent two iterations of the "evaluation and selection" loop. If time permitted, the team would have completed more iterations in order to conduct a more thorough analysis.

H. IMPLEMENTATION

Now that the final sixteen alternatives were selected, the next phase is to determine how Team A's suggested ORS architecture will be integrated into the current space environment. More detail to this phase will be included in a following chapter.

I. VERIFICATION

The very last stage in this process was to ensure that the final ORS architecture satisfied all of the requirements developed in the first phase. Those requirements that were not met would need further investigation on whether to accept or not accept the risk of not fulfilling those particular requirements and why. Majority of the mission areas accepted the risk of having gaps because a different alternative partly contributed to the mission.

IV. METHOD OF EVALUATION

During the MOE segment of the architecture process, the team began to develop a method that would be used to evaluate the alternatives that would be the eventual output of the evaluation phase. Knowing that the alternatives would include a variety of different means to meet the established requirements, the team envisioned difficulties in comparing each alternative to another (i.e. comparing "apples to oranges"). A quantitative analysis would provide the only way of comparing dissimilar alternatives. The team developed a scheme that would rank each of the suggested alternatives by score and provide an objective view of which alternative was superior to another, regardless of category or mission area. The score would include consideration of an alternative's responsiveness, capability, risk, and cost. Each of the areas to be evaluated was given a weight using a pair wise comparison method whereas each team member rated each evaluation area against the other. The mean of all the members inputs were entered into an algorithm that used the Analytic Hierarchy process as implemented in the expertchoice® decision support software to determine the weighting coefficients for the final score equation. Two versions of the equation were developed; the first (Equation 1) contained variables for Responsiveness, Capability, Risk and Cost (RCRC) and the second (Equation 2) treated cost as an independent variable and was therefore not included.

$$\text{Alternative Score (RCRC)} = \left[X_1\left(\frac{R}{9}\right) + X_2\left(\frac{Ca}{3}\right) + X_3\left(\frac{Ri}{5}\right) + X_4\left(\frac{C}{5}\right) \right] \times 100 \qquad \textbf{Equation 1}$$

Where $X_1 = 0.54$
$X_2 = 0.10$
$X_3 = 0.12$
$X_4 = 0.24$
(Inconsistency value of 0.02 where <0.1 is desirable)

$$\text{Alternative Score (RCR)} = \left[X_1\left(\frac{R}{9}\right) + X_2\left(\frac{Ca}{3}\right) + X_3\left(\frac{Ri}{5}\right) \right] \times 100 \qquad \textbf{Equation 2}$$

Where $X_1 = 0.67$
$X_2 = 0.18$
$X_3 = 0.15$
(Inconsistency value of 0.01 where <0.1 is desirable)

The alternatives were ranked by their RCRC or RCR score from highest to lowest. This aided the IPT in making decisions regarding which alternative(s) would be included in the final architecture. Although a higher overall score was generally favored, consideration was also given to cost in the second analysis as well as gaps created in the requirements had a particular alternative been left out. Each potential alternative was also measured against the constraints and restraints developed at the beginning of the architecture process. To eliminate some alternatives, an assumption was made that some portions of the current space enterprise architecture (e.g. GPS BlkIII, AEHF, ICBM inventory, etc.) would fulfill requirements until replaced by a new capability or end of life of that system. An explanation of each of the four criterion is included below.

A. RESPONSIVENESS

<u>Responsiveness (R: Total Possible Points = 9)</u>:

Is alternative responsive to all customers across all utility levels?

An alternative's responsiveness score was determined a survey of space professionals (14 total respondents; see App. C for Survey Instructions and Example Score Sheet). Each alternative was evaluated for its responsiveness to each customer (DoD, IC, and Warfighter) at each utility level (Strategic, Operational, and Tactical). For example, if a particular alternative was thought to be responsive to all three customers at all three utility levels that alternative would receive a nine (9). If a particular alternative was thought to be responsive to each customer only on a tactical utility level that alternative would receive a three (3). Maximum score for each alternative was nine (9) and the minimum was zero (0). The mean score from all 14 respondents was used as the responsiveness score for any particular alternative.

B. CAPABILITY

<u>Capability (Ca: Total Possible Points = 3)</u>:

Does alternative maintain current capability, improve current capability, or create a new capability?

Capability was graded as an absolute; in other words no relative scale was applied. A capability provided by a particular alternative was either an existing capability, an improved capability (incremental) or a completely new capability. A new capability was given the highest score of 3 while an existing score was given the lowest score of 1 (see Table 1 below)

Points	Capability
3	Completely New Capability
2	Improved Capability
1	Existing Capability

Table 1: Capability Score Breakdown

C. RISK

Risk (Ri: Total Possible Points = 5):

What are the technological risks associated with selected alternatives?

Each alternative was given a risk score based on its Technology Readiness Level (TRL) as determined during the open source Technology Review portion of the architecting process. Table 2 below show the TRL definitions used and Table 3 shows the points applied to each level of readiness.

TRL	Description	Risk
9	Actual system “flight proven”	Low
8	Actual system “flight qualified”	Low
7	Prototype demonstrated in space	Low
6	Prototype demonstration in relevant environnent	Low
5	Breadboard demonstrated in relevant environment	Mod.
4	Critical function demonstrated in lab	Mod.
3	Analytical/experimental proof of concept	Mod.
2	Conceptual design formulated	High
1	Basic principles observed	High

Table 2: TRL Levels

Points	TRL Level
5	TRL 9
4	TRL 7 & 8
3	TRL 5 & 6
2	TRL 3 & 4
1	TRL 1 & 2

Table 3: Risk Score Breakdown

D. COST

Cost (C: Total Possible Points = 5):

Analysis of relative cost of capability to total architecture costs.

For cost analysis the group developed five Cost Categories (or bins). The bins were modeled in part to be similar to the DoD 5000 Acquisition Category sub-divisions and were intended to capture the relative ease (or difficulty) at which each alternative would pass the budgeting process. Table 4 below show the breakup of cost category. Where applicable and when the information was available, total cost estimates included those incurred for R&D and one year of Operation and Maintenance (O&M).

Points	Cost Categories (CostCat)
5	< $ 100 M
4	$ 100 M - $ 499 M
3	$ 500 M - $ 1.49 B
2	$ 1.5 B - $ 9.99 B
1	>= $ 10 B

Table 4: Cost Category Score

V. DECISION

The team began the selection process by choosing the top alternative from each of the JP 3-14 mission and sub-mission areas, which provided fourteen alternatives that would serve as the beginning point for the trade-off analysis to follow. Four of the first fourteen alternatives were immediately dropped for the following reasons; an assumption that portions of the current NSSE architecture would remain until subsequently replaced or end of life negated the need for one of the alternatives, two alternatives were already incorporated into other mission areas and the final alternative dealt with developing doctrine for space weapons. The remaining ten alternatives were validated for inclusion into the final architecture. At that point each mission area IPT reviewed the original list of sixty-one alternatives to suggest any more that should be included based on the risk incurred of gapping requirements. Each suggested alternative was evaluated based on its overall score, cost and feasibility of implementation. This second to final iteration of trade-offs produced a list that included twenty-four alternatives. During the last iteration of trade-offs ten alternatives were combined in whole and one was a hybrid of all of one and part of another to produce the final list of sixteen alternatives (The Sweet Sixteen). Below is the OV-1 diagram of the complete Team A ORS Architecture of sixteen alternatives with a total cost of $39.8B. Each of the final alternatives will be discussed in depth in the following pages.

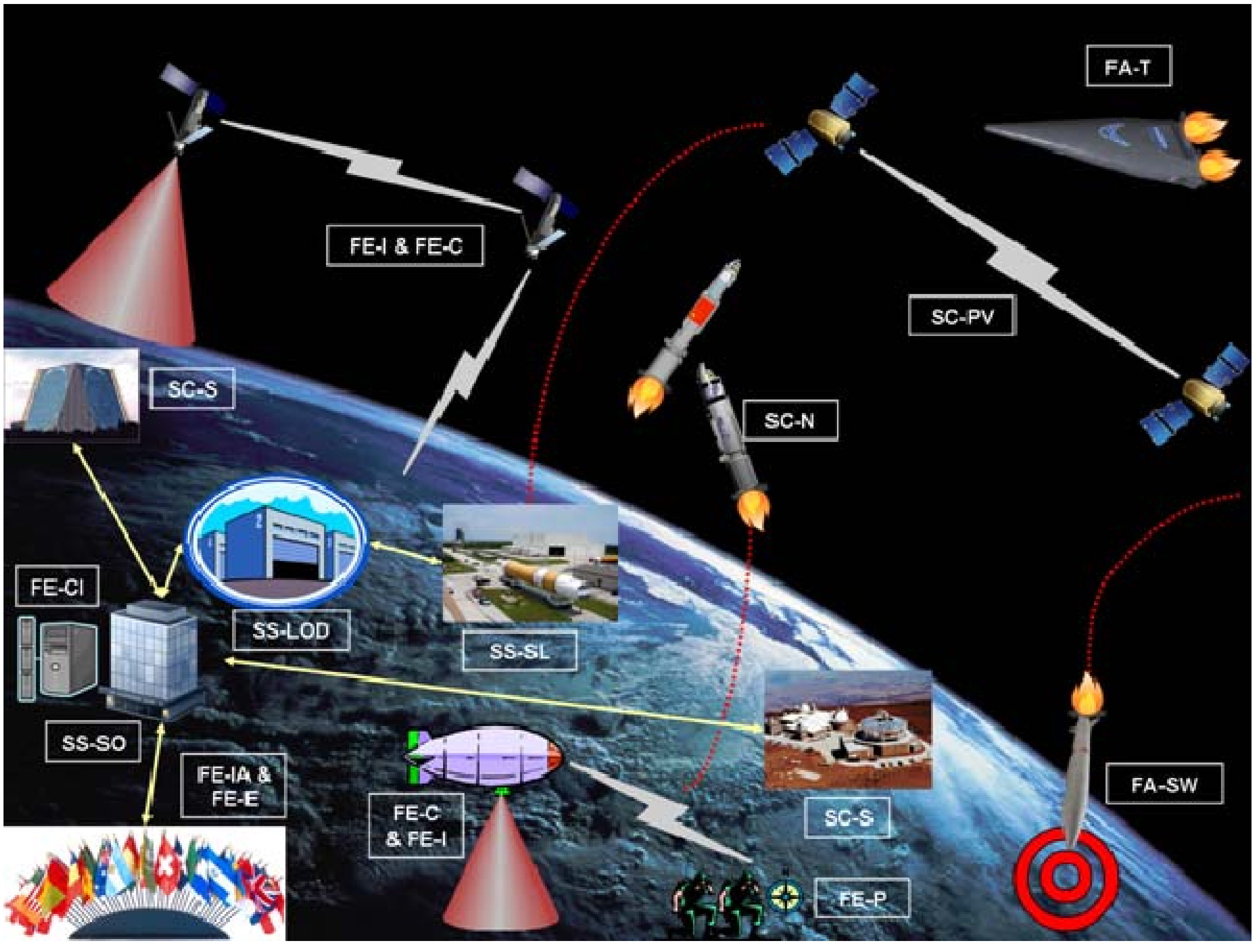

Figure 2: Team A ORS Architecture OV-1 Diagram

A. SPACE SUPPORT

1. Definition

Combat service support operations to deploy and sustain military and intelligence systems in space. The Space Support Mission Area includes launching and deploying space vehicles, maintaining and sustaining spacecraft on-orbit, and de-orbiting and recovering space vehicles, if required.

2. Space Launch (SL) Final Alternative

SS.SL.2: Modify current launch pad infrastructure (Cape Canaveral)

The final alternative to support the Space Launch (SL) mission area involves building two additional Delta Evolved Expendable Launch Vehicle (EELV) Horizontal Integration Facilities (HIF's) adjacent to the Delta launch pads at Cape Canaveral. Additionally, two work shifts would be utilized at each HIF (three at Cape Canaveral and one at Vandenberg Air Force Base) and "plug and play" technology will be introduced into the Delta boosters. Together, these three changes would drastically reduce pre-pad processing time for Delta vehicles from 24 days to nine; would decrease on-pad processing time from ten days to three; would decrease post-launch pad refurbishment time from 20 days to ten; and would reduce booster trouble-shooting/ repair times. In turn, the launch capacity of the Delta EELV can be increased from approximately 14 per year (current launch rate) to as many as 124 per year. When added to the launch capacity of the Atlas EELV, the overall launch capacity for the architecture will equal approximately 136 launches per year.

In order to determine a realistic and cost-effective method of increasing the current launch capacity, and in turn, responsiveness, both the Delta and Atlas EELV's were examined. As mentioned above, the Delta EELV utilizes horizontal integration to build-up its boosters and integrate its payloads. By doing so, Delta is able to assemble the vehicle in a facility away from the launch pad, thus minimizing on-pad processing time, which allows for more throughputs on each of Delta's four launch pads (three at Cape Canaveral, one at Vandenberg). Additionally, the Delta HIF contains three processing bays and two storage bays, allowing

three separate boosters to be assembled simultaneously, while also providing room for two completed vehicles to be stored prior to launch.

In comparison, the Atlas EELV utilizes Vertical Integration Facilities (VIF's) to vertically build-up its boosters and integrate its payloads. Within the VIF, there are only two bays for assembly and/ or storage, thus limiting their vehicle throughput. This two-bay configuration greatly restricts vehicle movement within the VIF due to floor space constraints and can lead to complete work stoppages if a problem arises when a vehicle is in the single transfer isle. Additionally, the use of vertical integration can be problematic when troubleshooting either the booster or payload, as "destacking" the rocket is often needed, which entails extensive processing/ pad tie-up times. This constraint is further exacerbated by the fact that Atlas only has two launch pads (one at Cape Canaveral, one at Vandenberg). Based on these constraints, the Atlas EELV portion of the program takes as long as 60 days to process and launch a single vehicle, while only meeting a six to 12 launch per year target.

Based on these findings, our space launch alternative concentrated on further improving the Delta portion of the EELV program, since this would provide a greater return on investment based on cost and launch capacity, when compared to Atlas. This option will enable each Delta launch pad to have its own dedicated processing facility in order to decrease prelaunch processing time and increase vehicle throughput.

Four Criteria

a. <u>Responsiveness</u>

By building two additional HIFs, adding additional work shifts at each facility, and by utilizing plug and play technology, this alternative was able to greatly increase the architecture's overall launch responsiveness to all three user communities (DoD, IC, Warfighter) and across all three levels of support (Strategic, Operational, Tactical). This level of responsiveness (7.1 of 9.0) was mainly due to the ability to increase the overall launch capacity from 20 per year to potentially 136 launches per year (combined Delta and Atlas). Additionally, responsiveness was further enhanced due to the dramatic decrease in pre-launch processing time (from 24 to 12 days) and the ability to store launch spares (two) within each HIF if needed.

b. Capability

In terms of capability, this alternative was an improvement to current technology (Capability Score: 2.0). This was based upon the idea that the greatly reduced processing time (from 24 to 12 days) would bring about a tremendous improvement in the overall launch capacity (from 20 to 136 per year) and thus, provide an overall improvement in the architecture.

c. Risk

Delta has utilized HIFs in the processing of their EELV for over ten years, subsequently the TRL for this alternative was deemed to be extremely mature (nine out of nine). Therefore, it received the maximum number of points available (five of five) and should, in turn, pose little to no risk in implementation.

d. Cost

In order to accurately estimate the potential cost of this alternative, historical cost data on the original HIF construction was utilized. Based on reports in "Space Florida", each HIF cost approximately $24 million to build in 1998, for a total cost $48 million for the two required facilities. Additionally, work shift costs were based on 50 workers per shift (current manning level) at $100,000 per person per year, for a total cost of $30 million for six additional work shifts (Cost Score: 5.0, Degree of Certainty: High).

Although the construction costs utilized for the architecture were somewhat dated and could have been amortized ten years to determine their cost in today's dollars, this level of fidelity was deemed unnecessary. Because this alternative was one of the least expensive within the overall architecture, even adding a 50 percent cost growth would have still left it close to the top of the lowest cost reference score.

Possible Setbacks (constraints / restraints)

The only possible setback associated with this alternative involves possible impingement upon the Cape's wildlife refuge sanctuary. Because the entire base is located on

a wildlife preserve, any new construction project must be fully vetted and approved by wildlife officials. Therefore, it is possible that the construction of two new buildings could run into opposition over wildlife impingement concerns. However, based upon previous construction efforts, this possibility is considered unlikely.

3. Launch On Demand (LOD) Final Alternative

SS.LOD.2H: Build-and-launch replacement satellites in weeks for national systems and within 72 hours for small satellites such as TACSAT

The final alternative for the Launch on Demand mission area involves drastically reducing satellite build/ launch times from years to weeks for national systems, and from weeks to 72 hours for small satellites such as TACSAT. This capability enables the architecture to quickly respond to the loss of a national or theater satellite by providing an interim stopgap capability until a full replacement satellite could be built and launched. In essence, this alternative would give the architecture a “ready alert” capability to combat unanticipated capability losses. Although this interim stopgap system would likely be less capable than its predecessor would, it would still be able to provide some level of capability to help mitigate the complete loss in capability of an IMINT, SIGINT, COMMS, etc vehicle within a given plane. In addition to replacement payloads, “ready” boosters would be stored within the HIF storage bays to be quickly mated to a given replacement payload as mentioned above. Together, these two options would allow for rapid replenishment (in as little as 72 hours) of lost assets due to system failure or hostile action.

The benefits of such a capability would be obvious, especially during open hostilities with another nation. However, in order to implement such a capability, the acquisition process would require a paradigm shift in the way spacecraft are currently procured and built. Instead of building satellites as one-of-a-kinds, efficiencies would have to be gained using several common bus sizes, along with several common plug-in-play payload types (IMINT, SIGINT, COMM, etc). By moving towards this type of configuration, a given contractor could be put on retainer in order to quickly build a replacement satellite in weeks for a national system, vice years or even decades, as is currently the case. This same idea would also apply to smaller

satellites of the TACSAT size and variety. This type of procurement shift would also allow for quicker introduction of new technology, since bus and payload sizes would be standardized, therefore minimizing research and development time.

Overall, this alternative will provide the nation with a responsive defense and deterrence means for its satellite constellations that it currently does not possess. By utilizing cookie-cutter satellites with plug-and-play technology, the space architecture can greatly improve the basic space acquisition process, enable quicker introduction of new technologies with much less risk and cost, and enable the replacement of lost assets within weeks and even days.

Four Criteria

a. <u>Responsiveness</u>

By utilizing common bus types and payloads for both national systems and smaller satellites, this alternative was able to greatly enhance the architecture's overall launch on demand responsiveness to all three user communities (DoD, IC, Warfighter) and across all three levels of support (Strategic, Operational, Tactical). This level of responsiveness (6.7 of 9.0) was mainly due to the ability to decrease the replacement time for a lost vehicle from years to weeks or even days.

b. <u>Capability</u>

Although at first glance this alternative may seem to be a step in the "less capable" direction based upon the discussion in the preceding section, the ability to quickly assemble and launch a space vehicle to meet an emerging mission need is truly revolutionary (Capability Score: 3.0). Not only will this capability enable the introduction of new sensors and technologies sooner, but also it will also likely serve as a strong architecture protection/ deterrence measure for all on-orbit spacecraft.

Because this alternative will enable the rapid replacement of virtually every strategic, operational, and tactical satellite on-orbit, it will demonstrate to potential adversaries that destroying any of our mission birds is pointless due to our replenish capability.

c. <u>Risk</u>

Since most of the technology required to implement this alternative is fairly mature (Risk Score: 4.0), it received high marks in this category. However, three aspects of this alternative need improvement in order to meet the desired capability. The first aspect involves the utilization of plug-and-play technology for both the bus and the payload. In order to obtain the flexibility and responsiveness desired, this form of integration will be required across the board in order to expedite build times in response to an urgent capability need, such as replacing a lost asset.

The second aspect needing improvement will be a conscious decision to move to less complex spacecraft that capitalize on incremental capability improvements, vice attempted leaps in technology. By making all spacecraft less complex (not necessarily less capable), industry will be better able to reduce required manufacturing times and in turn, increase responsiveness to emerging user needs. This approach also will help mitigate the often-fatal desire to make a single spacecraft do everything, vice limiting the number of sensors and missions on a given vehicle.

The third aspect needing improvement will involve the paradigm shift of building satellites in days and weeks, vice in years and decades. This shift will require a concerted effort on both the government and industry's parts to be successful. In adopting such an initiative, both sides will need to make concessions in terms of cost, schedule, and performance. By accepting incremental improvements in performance, both partners will be better able to manipulate costs and schedule in order to achieve the desired responsiveness this architecture requires.

d. <u>Cost</u>

Because this alternative involves a paradigm shift by both the government and the space industry, it was determined that implementation costs would be minimal (~$0). As with any procurement contract, the requirement to utilize common bus/ payloads, plug-and-play technology, and the requirement to provide replacement vehicles in weeks can be written into the contract when the Request For Proposal (RFP) goes out to industry.

Therefore, programmatic costs should be no more, and in reality less, than those of current space systems. (Cost Score: 5.0, Degree of Certainty: High)

Possible Setbacks (constraints / restraints)

Per the discussion above, there are two possible setbacks to this alternative. The first of these is the possibility that plug-and-play technology may not be fully integrated by all contractors by the 2025 timeframe. Although this occurrence is a possibility among some of the contractors involved, it seems unlikely that this would be the case for the majority of contractors.

The second and more likely possible setback involves the need for a complete acquisition paradigm shift in order to be responsive. Changing both government and industry to shorten the procurement time and to think incrementally vice exponentially will be problematic, if not nearly impossible. This will require a commitment on both sides in order to make such a huge shift possible. However, such efforts have been done successfully before (as exemplified in the CORONA and SR-71 programs) and can be done again.

4. Satellite Operations / Telemetry, Tracking, and Control Final Alternative

SS.SO.1, SS.SO.2, SS.SO.3: Single Space Agency

The final alternative for the Satellite Operations / Tracking, Telemetry & Control mission area involves folding all of the various space entities (NRO, NGA, JFCC SPACE etc) and their associated training, tasking, and mission responsibilities under one overarching space agency. In formulating this alternative, it soon became clear that combining each of the three separate alternatives into one, all-encompassing alternative under the guise of a Single Space Agency, made logical sense. Within this construct, three areas would be addressed: Mobile Training Teams (MTTs), a National Tasking Board, and a Single Space Agency.

The first area of the alternative involves standing up and utilizing Mobile Training Teams (MTTs) to educate space asset users at all levels on capabilities, product request procedures and tools available. This training would be available to users at all levels (Strategic, Operational, and Tactical) and would consist of four “4-man teams” per Combatant Commander (COCOM). This would enable each of the six Combatant Commanders (Southern

Command (SOCOM), Central Command (CENTCOM), Northern Command (NORTHCOM), European Command (EUCOM), Pacific Command (PACOM), and Africa Command (AFRICOM)) to have four MTTs available to forward deployed users in order to conduct training that enables each level of the command structure to capitalize on the space-related tools and products available. In addition, there would also be an option to utilize low- and high-bandwidth web-based training linked to each COCOM's website, but hosted and maintained by the Single Space Agency. Together, these two approaches would make for better "consumers" and enable the individual users to make space products responsive to them.

The second area addressed by the alternative involves the establishment of a National Technical Means (NTM) Tasking Board to prioritize satellite tasking on a daily and long-term basis. This capability will leverage all of the existing system capabilities through of one overarching, jointly manned tasking organization capable of making priority, rapid re-tasking decisions for all users. In order to accomplish this, a Fusion Coordination Cell would be established to monitor and assimilate real-time information from NTM and other support satellites and use that information to re-task assets as required to support both the Department of Defense (DoD) and the Intelligence Community (IC) "on-the-fly". By bringing all satellite sensor information together within one cell, the ability to form one common operational picture can be truly realized.

The final area addressed by this alternative was the formulation of a single, all encompassing Space Agency. Of all of the alternatives examined within our ORS architecture, this alternative was found to be the most important in terms of its responsiveness and its capability. Because of the fractured and often duplicative nature of the current space enterprise in the areas of space control, tracking, tasking, training, and acquisition, the formulation of a single entity is paramount to making all of the various pieces of the architecture work together in a cohesive, responsive manner.

By forming a Single Space Agency, the architecture will be better able to establish a "flatter" organizational structure, enabling decisions to be made quicker and at lower levels. In addition, coordination and tasking will now take place under one umbrella and will result in better customer service for all end users. Additionally, the Space Agency would be comprised of both space experts and space acquisition personnel, but also members of each warfare

specialty within each military service. The agency would also be comprised of a large contingency of intelligence and interagency personnel representing each of the various space stakeholder entities.

The final necessity for a Single Space Agency is the need for a Joint Space Acquisition Office that supports, articulates, and coordinates the needs of all of the services and organizations that utilize space. This requirement alone provides a compelling justification for such an organization and will provide a great deal of responsiveness to the architecture.

Four Criteria

a. <u>Responsiveness</u>

As a three-part alternative, a Single Space Agency increases responsiveness through education, quicker decision-making, economies of scale, and a single chain of command. Because there are numerous commands and end users who are ignorant of how best to use space to their advantage, i.e. capabilities, product request procedures, and tools available, a need exists educate them properly. By utilizing MTTs, the COCOMs will be able to greatly reduce the learning curve resulting in a more efficient and responsive use of space assets and products (Responsiveness Score: 6.6).

A second aspect of this alternative establishes a Fusion Cell to ensure all re-tasking decisions are made rapidly utilizing one overarching, jointly manned tasking organization that reduces coordination requirements and associated response times. With all critical players included within the NTM board, issues can be brought forth immediately and acted on quickly (Responsiveness Score: 6.2).

The third portion of the alternative entails gathering all space entities under one command that, by default, will function more quickly than each could separately. Additionally, the single space agency will benefit enormously and become more responsive from having its own acquisition personnel and its own streamlined space acquisition process (Responsiveness Score: 7.8).

b. Capability

Although this alternative is not a "new" idea, we determined that it should still receive a 3.0 as a "New Capability" because of the exponential improvement it will bring in operations and acquisition. Therefore, the anticipated gain in effectiveness warrants such a score.

c. Risk

All portions of this alternative, including the formation of MTTs, the creation of a joint tasking board, and the consolidation of multiple agencies/ organizations into one entity has been done previously (i.e. TRANSCOM, SPACECOM, etc). Therefore, this effort is following a proven path and has earned a risk score of 5.0 (the equivalent of TRL 9).

d. Cost

The total cost of this alternative is approximately $113M with an overall degree of certainty (DOC) of "medium". For the MTT portion, we determined that four four-man teams are required per each of the six COCOMS (SOCOM, CENTCOM, NORTHCOM, EUCOM, PACOM, and AFRICOM), for a total of 96 personnel. In order to maintain consistency, we assumed a man-year cost of $100K. That leads us to a recurring yearly cost of $9.6M (Cost Score: 5.0, Degree of Certainty: High) to ensure that each COCOM maintains 16 MTT personnel each.

The second part of the alternative refers to the NTM tasking board. We have again assumed $100K per man-year, and the tasking board will require 24/7 manning, with three shifts of 10 personnel each. This portion of the alternative will require 30 personnel with a yearly cost of approximately $3M (Cost Score: 5.0). This falls within a Medium Degree of Certainty due to the uncertainty surrounding the makeup of the board and the amount of tasking requirements per shift. Therefore, we considered it prudent to err on the side of caution and assume 30 personnel 24/7/365.

The third portion of the alternative carried with it the least accurate cost estimate. Due to our limited cost estimation background and a lack of data on combining several

organizations into one new parent organization, we were forced to guess on a cost estimate and eventually went with $100M (Cost Score: 4.0, Degree of Certainty: Low). This estimate may be overly generous and there may be less expense incurred due to cost savings from utilizing existing infrastructure. On the other hand, this estimate may also grossly underestimate the myriad of costs associated with merging numerous entities. Therefore, this estimate should be utilized with great caution.

Possible Setbacks (constraints / restraints)

As is possible with any large reorganization/consolidation effort, an organizational name change and new stationary does not mean that things will naturally be better and more efficient. This alternative requires a paradigm shift from current thinking of “that’s the way we’ve always done it” to “this is the way we are going to do it”. As discussed above, numerous advantages can be gained by implementing this alternative.

Additionally, a task of this magnitude will require significant coordination and cooperation from all entities involved in the consolidation/ reorganization effort. In addition to the organizational cooperation involved, Congressional buy-in will also be required in order to align the various funding restrictions and agency reporting responsibilities.

5. Space Support Gaps

The final Space Support Alternatives met all requirements except:

- Alternative launch options for broadened orbit choices and increased launch capacity, Inexpensive, efficient, flexible lift vehicles,
- On-orbit capability to extend satellite service-life and upgrade/change mission capabilities,
- A “ready-alert” capacity (satellites & boosters) to launch a replacement satellite, of each mission type (IMINT, SIGINT, COMM, etc), within 72 hours,
- All future assets capable of communicating with each other, regardless of mission area.

Alternative launch options was initially formulated to provide more launch options and in turn, more launch capacity over the current architecture. Various alternatives, such as Sea Launch, Space Ports, and Falcon were examined to determine their possible utility and advantage within the new architecture. However, it soon became apparent that their capability and maturity was not going to be significant enough to contribute to an increase in launch capacity in the 2025 timeframe. Additionally, both Sea Launch and the various proposed Space Ports were not going to be capable of launching large, national system-type satellites into GEO or even LEO orbit. Therefore, their utility was determined to be limited. Since the number of launches anticipated from the Space Launch alternative, described above, totaled 136 per year, the need for additional launch options was deemed unnecessary. Therefore, intentionally not meeting this requirement was determined to be an acceptable risk, given the fact that the architecture's launch capacity was fully met with alternative number one. Our initial research at the outset of this project, examined inexpensive, efficient, and flexible lift vehicles as a possible alternative in the 2025 timeframe. However, current technology estimates indicated that there would be no new or truly *revolutionary* lift vehicle by the required timeframe. Therefore, this requirement went unmet.

The group decided that an on-orbit capability was unnecessary, even though this option is a unique approach that extends the service life of a given satellite through refueling and component upgrades. After ranking all of the various alternatives (based on responsiveness, capability, & technology risk) and examining the utility to the final architecture, a final decision was made to exclude it from the architecture. Based upon these inputs, its exclusion was deemed an acceptable risk, since our enhanced launch capacity and improved acquisition process would be able to provide all of the mission capability required, and at a much lower cost.

Although the "ready-alert" requirement is unmet, it was determined that this was an acceptable risk within the architecture, since our Space Launch alternative will be able to provide all of the launch capacity (in a somewhat affordable manner) required in 2025. The use of the current EELV program is able to meet both the weight and capacity requirements of our ORS architecture. However, we recommend that commercial companies and DoD continue to research and pursue such technologies for possible use in the future. This

requirement was initially thought to be a critical component of the responsive Space Support Mission Area and more specifically, responsive Launch On Demand. However, as other alternatives were formulated, it became apparent that the $4 billion dollar price tag associated with this alternative made it prohibitive. Additionally, two factors enabled the exclusion of this alternative to be an acceptable risk. The first factor was the rapid response time associated with the Launch on Demand alternative discussed previously. By partially mitigating the loss of a national system within 72 hours, this capability greatly decreased the need for a $4 billion dollar "ready alert" capability. The second factor that weighed heavily in the decision to forgo this requirement was the strong political and budgetary argument against storing billion dollar satellites in a warehouse until needed. In an era of ever-shrinking defense budgets, it is unlikely that this rationale could have been sold to either the government or the taxpayers. Therefore, it was determined that the requirement was unwarranted.

The requirement for cross communication was met under several mission areas outside of Space Support and therefore not covered under our alternatives with no induced risk.

B. FORCE APPLICATION

1. Definition

The application of force would consist of attacks against terrestrial-based targets carried out by military weapons systems operating in or through space. The force application mission area includes ballistic missile defense and force projection.

2. Transport Final Alternative

FA.5: Hypersonic delivery vehicle

The ability to deliver personnel, logistics, or weapons to any location in the world in less than two hours would provide the United States a great advantage over any potential adversary. Having this capability may deter potential adversaries since they know any

negative action on their part could lead to a quick retaliation from the United States. It would provide a forward presence without forward deployment of forces.

In the non-combative arena, a hypersonic suborbital vehicle help deliver supplies to areas devastated by a natural disaster. It could also be used to resupply United Nations forces in remote areas. It was determined six vehicles could cover a majority of theaters/contingencies depending on re-usability. They would be launched using current launch technology (Atlas and Delta rockets) from exiting launch sites in CONUS to anywhere world wide.

The team decided to keep based on numerous other-than-military applications this capability would provide: Humanitarian assistance to inaccessible disaster areas, replacement for ICBM's, rapid reaction force / rapid reinforcement capability, SOF insertion in denied access regions, Operational Maneuver from the States (OMFTS), etc.

Four Criteria

a. <u>Responsiveness</u>

The hypersonic suborbital vehicle received a score of 5.7 for responsiveness because it does not address any Intelligence Community needs.

b. <u>Capability</u>

Since a hypersonic vehicle would be a new capability that the United States does not currently posses, it received a capability score of 3.0.

c. <u>Risk</u>

Much of the technology required to build a hypersonic suborbital vehicle does not exist yet. This immaturity of technology led to the vehicle receiving a technology risk score of 2.0.

d. Cost

The lack of current technology to build a hypersonic suborbital vehicle requires a larger amount of research and development funding. This large research and development effort led to a cost score of 2.0. The cost associated with the vehicle has a low degree of certainty and was based on the SpaceShip One endeavor.

Possible Setbacks (constraints / restraints)

One of the biggest restraints the hypersonic suborbital transport vehicle will face is the enormous amount of resources it will take to develop, build, and field the vehicle. In a government that is stretched thin on money, attempting to divert a larger portion of the budget to development of the hypersonic suborbital vehicle will face an uphill battle. In order to fund the vehicle, funding from other programs will have to be used, which means another government funding program will be impacted. The hypersonic vehicle may not have enough priority to receive the additional funding or other program funding required to proceed with its development.

The hypersonic vehicle will not address the intelligence community. It primarily assists DOD strategic, operational, and tactical customers along with the warfighter at each of those levels in their persecution of small contingencies and humanitarian operations. The intelligence would have little use of a hypersonic vehicle.

One of the biggest constraints right now is the technology needed to build and fly a hypersonic vehicle. Hypersonic engines are all but undeveloped. There are a few commercial ventures taking place that researching these engines, but they are costly and unless there is a commercial market for such engines the time and cost to build them may hinder their development. Also, very little research has been performed to attempt to make the ballistic re-entry ride compatible with human physiology. Being capable of delivering a squad of warfighters to a contingency area in less than two hours does no one any good if those warfighters are unable to fight once they disembark the vehicle.

Another issue with the use of a hypersonic suborbital vehicle would be vehicle recovery. Since the vehicle would be launched via an Atlas of Delta rocket from the U.S., the question arises as to how the vehicle could be brought back to the U.S. and reused. Along the same lines would be the question of how the troops that were inserted into the area would be retrieved once the mission was over.

3. Space Weapons Final Alternative

FA.3, FA.4: Permanent and Non-permanent effects space based weapons

Although there are many reasons to not develop and place weapons in space, mainly existing conventions that space is neutral territory, analyzing this alternative purely from a military capability point of view lead the group to believe that now is the time to begin taking advantage of the strategic and tactical “high ground” space provides.

For the purposes of this study the weapons systems discussed would be space based with effects against terrestrial targets. The weapons would be tasked in a similar manner to the current Joint Targeting Process and would provide the commander another weapon to integrate into a combined arms style of warfare.

Four Criteria

a. Responsiveness

Although this alternative was seldom ranked as responsive to any of the Intelligence Community it was viewed as greatly increasing the responsiveness of space to both the strategic DoD user and the operational and tactical Warfighter. (Responsiveness Score: 5.5 and 5.5)

b. <u>Capability</u>

The capability to deliver weapon effects terrestrially from a space based asset is a completely new capability (Capability Score: 3.0 and 3.0)

c. <u>Risk</u>

The technology readiness levels of the mix of permanent and non-permanent effects weapons varied based on which technology was examined. In general, the technology required has already been tested in one form or another but has yet to be tested from space. (Risk Score: 3.0 and 5.0)

d. <u>Cost</u>

The cost for both permanent and non-permanent effects weapons systems were both assessed with a Medium Degree of Certainty, based on the fact that both technologies have not yet been fully developed so O&M costs could only be estimated. A total cost for the architecture required would be approximately $7.9B (Cost Score: 2.0 and 2.0).

Possible Setbacks (constraints / restraints)

The main constraints this alternative would have to deal with include finite resources both in both budget and political will. The weaponization of space would require the United States to divert a large portion of funding for conventional weapons. It would also require the U.S. to withdraw from or re-negotiate several existing treaties on the topic of the weaponization of space.

The main restraints involve the physics surrounding the operating procedures of delivering both permanent and non-permanent weapons from space as well as the current technological readiness level of such a capability.

4. Force Application Gaps

The final Force Application Alternatives met all requirements except:

- Relationships with commercial space port entities.
- Develop Joint Doctrine for Fires

Both gaps were deemed to be acceptable because implementation of the Space Support alternative to increase efficiencies in current launch infrastructure, and any commercial capability would not required.

Also, implementation of the Space Support alternative to re-organize the National Security Space Enterprise will establish proper authority and appropriate body to develop doctrine regarding space based terrestrial effects fires.

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C. FORCE ENHANCEMENT

1. Definition

Force enhancement operations multiply joint force effectiveness by enhancing battlespace awareness and providing needed warfighter support. There are five force enhancement functions: integrated tactical warning and attack assessment, environmental monitoring, communications, and position, velocity, time, and navigation. They provide significant advantage by reducing confusion inherent in combat situations. They also improve the lethality of air, land, sea, space, and special operations forces (JP 3-14, IV-8). One alternative is included for each of the five force enhancement functions. Two additional force enhancement alternatives were also included in our architecture: complete integration with terrestrial systems and tactical communications and imaging.

2. Indications, Tracking, Warning, and Attack Assessment (ITW/AA) Final Alternative

FE.IA.2: Create Joint Ventures with Other Countries

Creating joint ventures with other countries was chosen as the best ITW/AA alternative. As a whole, this sub-mission area is currently viewed as being responsive. Keeping this in mind the goal with this alternative was to find a way to continue executing this mission while making the entire architecture more responsive. This can be accomplished by working with our allies to perform ITW/AA. By combining our efforts with others we can perform this mission with less manpower and resources.

Four Criteria

a. <u>Responsiveness</u>

A multi-party ITW/AA system will be more responsive. When more countries are devoting resources to this mission there will be more resources available for use. This could translate into more assets providing increased coverage to more users or into increased capabilities (Responsive Score: 5.5)

b. <u>Capability</u>

There will be an improvement in the capabilities associated with this alternative. These improvements will stem from the additional resources being devoted to ITW/AA. The same rational that makes this alternative more responsive also makes it more capable (Capability Score: 2.0).

c. <u>Risk</u>

This alternative does not rely on any new or experimental technology. It will continue to use proven technologies and equipment currently in use today. For these reasons this alternative has low technology risks (Risk Score: 5.0).

d. Cost

The cost estimate for this alternative is $5.5 million (Cost Score: 3.0). This uses a conservative estimate that we would spend half as much on this sub-mission area when partnered with allied countries (this percentage depends heavily on the number of partner countries). This percentage was then applied to the total spent on ITW/AA in the FY08 National Security Space Budget. Due to this method of estimation the degree of certainty for this estimate is low.

Possible Setbacks (constraints / restraints)

The biggest constraint for a combined approach to ITW/AA will be political views. Convincing members of our government along with our allies that this approach will benefit all parties involved could be difficult. Additionally, multi-national ventures can become very complex and complicated. Coordination in such an arrangement can be constraining.

3. Environmental Monitoring (EM) Final Alternative

FE.E.2: Create Joint Ventures with Other Countries

Creating joint ventures with other countries to share costs and resources was chosen as the best EM alternative. Here again, as with the ITW/AA alternative it was seen as the most sensible choice to work with our allies to meet this need. It's intuitively obvious to surmise that by combining assets and resources with our global partners that a better product can be produced more quickly and at a lower cost. This alternative also uniquely affords the approach of international non-military interest due to its overall inherent nature of being of great public interest. Although the data produced may certainly have military applicability in addition to the vast civilian uses, the technology used isn't so encumbered by the necessity for military secrecy.

Four Criteria

a. Responsiveness

The joint venture approach to EM will yield more responsive results. It's straightforward to see that with increased participation there will come numerous places where there exists the commitment to provide a needed product. This multi-national interest will provide the varied and wide interest needed to expedite the necessary R&D and expedite product development, which will, in turn, provide increased responsiveness when compared to a unilateral approach (Responsiveness Score: 6.1).

b. Capability

This alternative will also provide an increased level of capability (Capability Score: 2.0). This increase in capability will primarily come from the increase in resources available. The greater the resources devoted to this alternative the more likely it is that there will be an increase in capabilities. Capabilities may also be increased due to the likely increase in coverage areas due to the international participation and their unique, individual requirements.

c. Risk

This alternative will not require any new or experimental technology. This alternative's strength is based on its teaming efforts and not on its innovative technology. The technology risk will be minimal (Risk Score: 5.0)

d. Cost

The cost estimate for this alternative is roughly $230 million (Cost Score: 4.0). This uses a conservative estimate that we would spend half as much on this sub-mission area when partnered with allied countries (this percentage depends heavily on the number of partner countries). This fraction was then applied to the total spent on EM in the FY08

National Security Space Budget. Due to this method of estimation the degree of certainty for this estimate is low.

The individual participant cost for EM will also go down as a result of cost sharing. Each nation will not be uniquely and redundantly providing the funds necessary to provide a capability at a higher rate of responsiveness. Nations will not be paying alone for the R&D and product development of the same basic capability that some other nation has already paid for. The overall cost will be shared and the R&D and development costs will be a one-time thing instead of numerous times as in an individual nation approach.

Possible Setbacks (constraints / restraints)

Here again, as in the previous alternative, political views and goals of various governments could oftentimes be at odds with each other. It will take a concerted effort on all stakeholders' parts to genuinely work through disagreements so that the overall mission is successful. Also, with the increase in participation from numerous countries the coordination can become very complicated very fast.

4. Complete Integration with Terrestrial Systems Final Alternative

FE.CI.1: Expand Functionality of Current Information Systems to Include Cross System Sharing

The most advanced space architecture in the world would be useless if there was no way to move information from one location to another. This is why we created an important place in our architecture for system integration on the ground. A responsive architecture must contain the ability to quickly and easily transmit information on based on user demand. A key to responsiveness is the right information at the right place at the right time. Considering the current state of our space enterprise the best way to achieve this is to expand the functionality of current space related information systems to allow for cross system information sharing.

This could be accomplished by implementing compatible data formats, an accepted communication protocol, and mutual policies for access

Four Criteria

a. Responsiveness

Information flow is critical to a responsive architecture. An integrated system with information on demand will create a more responsive architecture for all users. This alternative will create a distributed data warehouse that facilitates information sharing on a scale never before seen by our space agencies (Responsiveness Score: 7.3).

b. Capability

An integrated information system will definitely bring improved capabilities to the overall architecture. Individuals and agencies that would never dream of sharing information with today's architecture could access each other's data just as easily as they check their email (Capability Score: 2.0).

c. Risk

This alternative carries a moderate technology risk (Risk Score: 3.0). The concepts and technologies have been proven and are in use today, but not on this large of a scale with this type of sensitive information. Even with compatible data formats and accepted communication protocols potential difficulties may exist with adapting existing systems to meet these new standards.

d. Cost

This integrated information system is estimated to cost $1.2 billon (Cost Score: 3.0). This is based on an information systems rule of thumb that on average an organization spends 15% of their annual budget on building and maintaining their

information systems. The FY08 National Security Space Budget was used as our architecture's total budget. This estimate has a low degree of certainty.

Possible Setbacks (constraints / restraints)

The biggest constraints that this alternative faces are the access policies for the individual agencies within our space architecture. Some organizations are extremely particular about how their information can be access and by whom. Getting past these information stovepipes will a difficult but very worthwhile task.

5. Communications Final Alternative

FE.C.3: Leverage the Commercial Market by Deploying Hosted Payloads on Future Launches

Reliable communication is a requirement for any responsive architecture. The communications alternative included in this architecture is to leverage the commercial market by deploying hosted payloads on private launches. Military communications payloads would be placed on commercial satellites, essentially leasing space on these satellites. In times of low utilization we could sell bandwidth to commercial users.

Four Criteria

a. <u>Responsiveness</u>

This alternative will add responsiveness to the current communications architecture (Responsiveness Score: 6.5). By only focusing on the payloads we will eliminate the need to devote resources to bus development for communications satellites. This frees up resources to work on designing and build better, more responsive, payloads. Additional resource could also mean more communications payloads on orbit providing responsive communications to more users.

b. <u>Capability</u>

Although this alternative does not set out to produce a new capability, it will provide improved capabilities to its users (Capability Score: 2.0). The factors that make hosted communications payloads more responsive are the result of improvements in capability.

c. <u>Risk</u>

This alternative involves low technology risks because it does not rely on new or unproven technology (Risk Score: 5.0). It's focus it on how we get our communications payloads into space, a practice that has been successfully demonstrated for several decades.

d. <u>Cost</u>

Space Mission Analysis and Design states that approximately 40% of a communications satellite cost is spent on its payload (SMAD, 799). By applying this percentage to the communications portion of the FY08 National Security Space Budget resulted in an estimated cost of $1.2 billion (Cost Score: 3.0). This method of estimation yields a lows degree of certainty.

Possible Setbacks (constraints / restraints)

This alternative will be constrained to the launch schedules of commercial satellite manufactures. Any difficulties or delays they encounter will affect our payloads. Our communications payloads will also be restrained once they are on orbit. Since we are leasing space on a bus we will not have tactical control of these satellites.

6. Position, Navigation, and Timing (PNT) Final Alternative

FE.P.3: Implement Inertial Navigation System (INS) Capabilities to operate until GPS signal re-established

This alternative was chosen as the best PNT alternative. INS technologies are already being widely used in smart bombs. There's a lot of work currently being done in industry using INS and Non-Inertial Sensors (NIS) technologies to try to help first responders such as firemen and policemen to locate individual responders within buildings. The idea here is to try to increase that capability to other non-weapon items to support continuous navigation (although degraded) in the absence of a reliable GPS signal.

Four Criteria

a. <u>Responsiveness</u>

Implementation of INS Capabilities will yield PNT responsiveness to our forces (Responsiveness Score: 5.4). The insertion of Inertial Measurement Units (IMU) and Micro Electrical-Mechanical Systems (MEMS) on both personnel and vehicle equipment will yield almost an immediate increase in both position and navigation capabilities. These position and navigation capabilities will be at a degraded quality to that provided by an un-impeded GPS signal.

b. <u>Capability</u>

This alternative will provide an increased capability in the position and navigation area (Capability Score: 2.0). This alternative provides this through a redundant (although degraded) capability for both position and navigation during times of denied access to a reliable GPS signal. This alternative will also provide enhanced Situational Awareness during times of GPS jamming and affords the opportunity for mission continuance.

c. Risk

The technology risk is minimal (Risk Score: 5.0). There is nothing new or revolutionary involved. This technology already exists.

d. Cost

The cost to implement this alternative has a medium-level degree of certainty and is ranked in the 2nd highest level of cost for proposed alternatives. The estimate for cost was based using 2 million DoD personnel out of 2,923,966 total personnel (FY2004), which includes roughly 680,000 civilians. Also, assuming that this equipment will be put on 500,000 various kinds of vehicles (aircraft, ships, tanks, HMMWVs, etc). Using this information along with an an approximate cost of $1200 for each IMU or MEMS on 2.5 million personnel and equipment gives an approximate cost of $3 billion. Assuming a 20% overhead for maintenance, replacement, and upgrades on a yearly basis would mean that there would need to be $600 million/year. For a total of $3.6 billion (Cost Score: 2.0)

Possible Setbacks (constraints / restraints)

A possible constraint to implementing this alternative is the relatively high initial investment of purchasing the necessary devices for all personnel and equipment. This initial shock may be somewhat alleviated by purchasing over a time period of 5 – 10 years based on a priority of fielding scenario. This would dramatically decrease the initial yearly investment. Another option may be to decide to take on some operational risk and decide to field this capability only to specific units and/or personnel instead of the entire force.

The other drawback to this option is that it's not exciting…there's nothing new here. It's not a brand-new fancy gizmo that everyone hasn't heard of. It's just implementing technology we already have to increase/provide additional and redundant position and navigation capability.

7. Intelligence, Surveillance, Reconnaissance (ISR) Final Alternative

FE.I.3: Add a Secondary Payload to Each Iridium "Next" Satellite to Provide Persistent Global Electro-Optical Coverage

Add a secondary payload to each Iridium NEXT satellite to provide persistent global EO coverage is the best ISR alternative. Iridium is the only company in the world operating a LEO constellation of 66 satellites with global persistence. Their original constellation is due to be upgraded. Currently, Iridium is looking for partners with an interest in adding secondary payloads to the Iridium NEXT constellation. This narrow window of opportunity allows us to add a persistent imagery capability globally without the Department of Defense assuming total responsibility of launching, operating, or maintaining the entire constellation.

Four Criteria

a. Responsiveness

This alternative is highly responsive as it would allow us to image any place in the world 'on-demand.' (Responsiveness Score: 6.9)

b. Capability

This is a new capability (Capability Score: 3.0). We have never had global imagery persistence. This capability would benefit tactical and strategic users alike. This would enable tactical users to get the latest imagery before an operation. This alternative would also allow strategic users to monitor a critical target until a national system is within range again.

c. Risk

This is seen as a low risk/high TRL alternative (Risk Score: 4.0). Similar payloads to this alternative have been produced in the past with good results.

d. Cost

The one time engineering cost for a 50kg imagery payload capable of providing sub-meter GSD from a 700km altitude is $20M (TACSAT 2 imagery payload bids were for $10M from 410km alt). The cost for building 66 payloads at $2M each would be $132M. The estimated Iridium fee for adding secondary payloads to their satellites would be $4.5M each for a total of $297M. The cost for engineering and building a system for tasking, operating, and maintaining the payloads would be $51M for a total of $500M (Cost Score: 3, Degree of Certainty: Low).

Possible Setbacks (constraints / restraints)

The only technical problem associated with this alternative might be the lack of a robust slewing and pointing capability on the Iridium communications satellite to support the imagery secondary payload.

8. Tactical Communications & Imaging Final Alternative

FE.C.4, FE.I.5: Invest in and deploy high-altitude long-endurance (HALE) airships capable of providing persistent imagery and communications to warfighters in a theater of operations.

This alternative is a hybrid alternative added to meet the growing need of battlefield commanders for increased imagery and communications support. By using high-altitude platforms to responsively fill the majority of warfighter needs in a given theater of operations, national assets can resume the role for which they were originally intended – strategic

intelligence gathering and long-range communications. This would allow these national assets to be more responsive to strategic national customers.

Currently, U.S. Army Space and Missile Defense Command (SMDC) is sponsoring an Advance Concept Technology Demonstration (ACTD) of High Altitude Airship (HAA) developed by Lockheed-Martin. Airships such as this offer pseudo geostationary satellite like capabilities. They can act as persistent imagery platforms and communications relays. At an operating altitude of 65,000 feet, they would have a 630 mile wide footprint.

Four Criteria

a. <u>Responsiveness</u>

HALE airships offer excellent responsiveness by delivering high resolution 'on-demand' imagery and/or video from anywhere inside it 630 mile footprint (Responsiveness Score: 6.2 and 6.2). Additionally, airships can provide a platform for high bandwidth communications relay that can provide regional support for Army Warfighter Information Network – Tactical (WIN-T) and the Future Combat System (FCS) before the full implementation of future communications satellite constellations (WGS/MUOS/AEHF/TSAT).

b. <u>Capability</u>

This is a new capability (Capability Score: 3.0 and 3.0). Airships of this size have not been constructed for decades and never unmanned and at such a high altitude. The payload goals are for 4,000lbs to 65,000 ft, 10 kW of power, capable of remaining on station for one year.

c. <u>Risk</u>

The key technologies required to build a HAA prototype are now available and tested – awaiting funding to proceed (Risk Score: 3.0 and 3.0).

d. Cost

Costs include $150M for R&D, the initial six airship for $300M ($50M goal per airship), and approximately $100M for ground infrastructure and operation and maintenance of the airship fleet (Cost Score: 3.0 and 4.0, Degree of Certainty: High and Medium).

Possible Setbacks (constraints / restraints)

The main setback is funding. The Missile Defense Agency (MDA) recently cut funding and transferred the program to SMDC. SMDC is trying to sustain the program. A prototype can be built and flight tested in 3 years depending on the funding profile.

9. Force Enhancement Gaps

The final Force Enhancement Alternatives met all requirements except:

- *Improved PNT anti-jam/jam detection capabilities*
- *Augment Current Architecture with GPS Block III enhancements*

We felt that not having the improved PNT anti-jam/jam detection capability was an acceptable risk. Jamming risk will be mitigated by enhanced Inertial Navigation capabilities in the absence of a guidance signal. If jamming does occur the mission will be able to be continued with a degraded capability until the jamming can be eliminated and a reliable GPS signal be re-obtained.

We also felt that not having the alternative of augmenting current Architecture with GPS Block III enhancements was an acceptable risk. This risk was assumed acceptable from our vantage point of ORS. We realize that not having some type of GPS satellite system is totally unacceptable in the foreseeable future. We made the assumption that since the GPS Block III initial contract has already been awarded that this required capability will be seen to completion.

D. SPACE CONTROL

1. Definition

Space control operations provide freedom of action in space for friendly forces while, when directed, denying it to an adversary, and include the broad aspect of protection of US and US allied space systems and negation of enemy adversary space systems. Space control operations encompass all elements of the space defense mission and include offensive and defensive operations by friendly forces to gain and maintain space superiority and situational awareness if events impact space operations.

2. Protection Final Alternative

SC.P.1, SC.P.7: Develop Protection Capabilities Across the Entire EM Spectrum for All National Space Assets.

The final space control, protection alternative was “Develop protection capability through entire EM spectrum for all national assets.” This was a hybrid of two previous alternatives. The first alternative stated, “Develop filters to protect optical/IR focal planes.” The second alternative was “Enhance anti-jam capabilities.” It was decided that these two alternatives were similar enough in their intent that they could be combined to achieve a greater level of responsiveness for our architecture. The desired end state for the protection aspect of space control is to ensure that our space assets have the ability to function as they were designed in order to provide the user information when it is needed.

To develop a protection capability through the EM spectrum future satellites must be designed with enemy capabilities in mind. Jamming and dazzling are two easy ways in which our enemy can deny the use of our space assets. Current capabilities such as filters, shutters, spot-beams, frequency hoping, and increased payload power exist to combat these enemy tactics. By ensuring that we equip all future national assets with these countermeasures we can maintain responsiveness of the systems.

Four Criteria

a. Responsiveness

We felt that developing a protection capability through the entire EM spectrum was extremely important when considering developing an architecture that is responsive . How could you possibly be responsive from space if your enemy is denying the use of your space assets? To achieve greater responsiveness we decided to implement existing technologies on all future national space assets. The use of filters and shutters on optical and IR platforms can ensure that our enemy's ability to blind these assets is reduced. Responsiveness can also be maintained through the use of frequency hopping and spot-beams on all our national assets to prevent the effects of jamming. Increased power on satellites, such as the GPS III constellation, will prevent our enemy the ability to jam our receivers without alerting us to the location from which they are jamming (Responsiveness Score: 7.4 and 6.7).

b. Capability

The overall capability of our architecture will be increased if these changes are implemented. By making it more difficult for our enemy to deny our use of space we are, by default, increasing our capability (Capability Score: 1.0 and 1.0).

c. Risk

Technology risk to implement these changes to future national space assets was small. All the changes that we are proposing exist in one form or another. The only risk involved is incorporating them all into one payload (Risk Score: 4.0 and 5.0).

d. Cost

The cost of implementing these additions to future payloads was based on research into existing technologies. Commercial vendors for optical filters were

researched. We based our estimates on prices for UV, Visible, and Near IR band pass filters available from the Andover Corporation of Salem, NH. Research into AEHF and GPS III was analyzed because they included similar capabilities (frequency hopping, spot-beams and increased power) as the changes we are suggesting for all future satellites. The cost for these technologies was taken from articles about the corporations that won the contracts for GPS III and AEHF. A medium degree of certainty for the cost of this alternative was given because we obtained actual prices from vendors for the filters. We found cost information from the contracts for AEHF and GPS III. Given their similar capabilities to the suggestions we had for implementation in the future, we used their cost information as a base for our cost estimate. We feel that this assessment could be argued to be a low degree of certainty given the high cost of this alternative (Approximately $14 Billion) for relatively simple technology (Cost Score: 1.0 and 5.0, Degree of Certainty: Medium and Medium).

Possible Setbacks (constraints / restraints)

The only possible setback for this alternative that we identified was the cost. Approximately $14 Billion dollars to equip all our future satellites with existing means to protect our capability throughout the entire electromagnetic spectrum. We did estimate the cost to be a medium degree of certainty, but again it could be argued that this estimate is high and we could have given our estimate a low degree of certainly. Either way, cost was our only hurdle to implementing this alternative.

3. Negation Final Alternative

SC.N.3: Develop Terrestrial Based Counter-ASAT System

This alternative includes developing kinetic as well as directed energy weapons to protect our space assets. We looked at employing these weapons from land, sea and air platforms.

Four Criteria

a. Responsiveness

The development of a counter ASAT system allows our entire architecture to maintain responsiveness (Responsiveness Score: 6.5). If a hostile country or non-state actor were able to shoot down our satellites we would lose the capabilities provided by those assets. Such actions would yield the United States less responsive and threaten the ability of the US to carry out some missions.

b. Capability

We assessed the alternative of a terrestrial based counter ASAT system as an improved capability (Capability Score: 2.0). We currently have much of the technology to make this alternative a reality. It would provide the US with greater capability in our quest to protect of national systems.

c. Risk

Our technology risk score was low because we have demonstrated the ability to destroy missiles in flight with programs such as the BMD program (Risk Score: 5.0). We have options within this alternative that have the ability to destroy an ASAT in it boost phase as demonstrated by the airborne laser and airborne interceptors. The development of the kinetic energy interceptor by the MDA for use by land and sea components is the biggest hurdle to procuring a successful terrestrial counter ASAT system.

d. Cost

Cost for this alternative was estimated using a 2007 study from the Center for Strategic and Budgetary Assessments (CSBA). The CSBA is an independent, non-partisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. The cost estimates that the

CSBA provided were for a twenty-year period and given on 2007 dollars. The CSBA looked at several options to achieve counter ASAT capabilities. The options included airborne interceptors, airborne laser interceptors, ground-based interceptors and sea based interceptors.

The airborne interceptor option would be able to intercept an ASAT in the boost phase. The boost phase is the part of the missile flight path from launch until it stops accelerating under its own power. It typically ends within the first 3-5 minutes of flight. Seven hundred kinetic-energy interceptors would be carried aboard aircraft with the ability to cover three defended areas, over North Korea or Iran, 24 hours a day. This alterative would cost approximately $1.3 Billion per year.

The airborne laser option would consist of seven modified 747 aircraft. Each would be equipped with a Chemical Oxygen Iodine Laser (COIL) laser. The COIL laser has the ability to disable an ASAT in the boost phase. It attacks at the speed of light at a range of hundreds of kilometers. This alterative would cost approximately $800 Million per year.

The ground based system option would consist of 100 platforms. The Missile Defense Agency is currently developing Kinetic Energy interceptors capable of intercepting ASAT in the boost phase with land-mobile platforms. This alterative would cost approximately $2.2 Billion per year.

The sea based interceptor option would consist of 9 Aegis destroyers armed with 35 missile interceptors each. Currently, Aegis destroyers are armed with SM 3 missiles that have the ability to shoot down ballistic missiles in the midcourse range. The Missile Defense Agency (MDA) is working with the navy to introduce kinetic energy interceptors that can be used to strike missiles in the boost phase of flight. This alterative would cost approximately $4.3 Billion per year (Cost Score: 2.0, Degree of Certainty: High / Medium).

We arrived at our cost estimate by looking at the costs provided by the CSBA. The CSBA had estimates based over 20 years. We took those cost numbers, adjusted for inflation and divided them by 20 to give us an estimate for one year. Since each of the

options provides us with the same capability we choose the most expensive option being the sea-based option costing approximately $4.25 billion per year. This represented the worst case for this alternative. Choosing the worst case would also allow us to consider a hybrid of the other counter ASAT alternatives that were less expensive. We gave the cost for this alternative a medium degree of certainty because of the cost information provided by the CSBA. We felt that we could not give the alternative a high degree of certainty because the kinetic energy interceptor is not yet available for the ground and sea aspects of this alternative.

Possible Setbacks (constraints / restraints)

The physics behind a counter ASAT system are quite challenging. For a terrestrial based counter ASAT system to be successful, we must have assets in theater. If we do not have assets in theater the distance needed for the interceptor to reach its target will be too great given the time it takes to shot down a satellite. This can especially be an issue if a country with a large land mass launches an ASAT from an area where we have little access.

Another possible setback is our ability to identify and engage multiple ASAT’s launched from a single site. The MDA is currently developing mobile high resolution, X-band class phased array radars with the ability to acquire, track, discriminate, classify, identify and estimate trajectory parameters and pass the information to fire control radars. Quick and accurate identification of ASAT is imperative if we are to successfully engage multiple ASAT’s.

The ability to intercept missiles in their boost phase can also be a setback. The successful development of the kinetic energy interceptor for land and sea based platforms is essential for the US to have a successful counter ASAT capability.

4. Surveillance Final Alternative

SC.S.3: Add more Electro-Optical and Radar Sensors Worldwide to Minimize Gaps in Surveillance Coverage and to Provide More Accurate Space Situational Awareness

Four Criteria

a. <u>Responsiveness</u>

Increasing the number of terrestrial based telescopes and radar systems in the current Space Surveillance Network (SSN) will improve responsiveness of our space architecture (Responsiveness Score: 5.8). The gains in responsiveness come from the reduction in the number of gaps in coverage and more timely updates on satellite activities. As more countries gain access to space, space real estate will become more congested. The expanded access and coverage will facilitate fusing space surveillance data into a more complete common operating picture.

b. <u>Capability</u>

Terrestrial based space surveillance is an existing capability (Capability: 1.0). However, increasing the number of observation post available will improve that capability have benefit for the entire architecture.

c. <u>Risk</u>

The technology risk associated with expanding the SSN is minimal (Risk Score: 5.0). The proposed additions are based on current technology that already exists within the surveillance network and will be easy to integrate into the existing infrastructure.

d. <u>Cost</u>

The cost estimate for expansion of the SSN was derived from a 2002 estimate for overhauling the Naval Space Surveillance System. In October 2002, Raytheon Integrated Defense Systems was awarded a $396 Million dollar contract to complete repairs on the network's nine field stations and dramatically improve its performance. The cost per sensor amounts to $44 Million dollars. For simplicity, we assumed that the cost of an optical sensor and the cost for a radar sensor would be the same. Given that there are

currently 28 sensors in the SSN network we could increase the number of sensors on the ground by 36 percent (10 sensors- 5 optical and 5 radar) at a total cost of $440 Million (Cost Score: 4.0, Degree of Certainty: High).

Possible Setbacks (constraints / restraints)

There are no foreseeable setbacks to implementing this alternative.

5. Prevention Final Alternative

SC.PV.1, SC.PV.2, SS.SO.4: Shift to cross-links on all future satellites.

This alternative was the result of merging two similar alternatives into a single hybrid that would better serve communications within the architecture. The hybrid alternative merged laser and radio frequency cross-links together.

Four Criteria

a. Responsiveness

Unlike the traditional "bent pipe" links, a satellite architecture fully integrated with cross-links could provide alternate paths for communications via satellite-to-satellite relays. These relays may be propagated through multiple radio frequency (RF) or laser cross-links (Responsiveness Score: 7.0 and 6.2 and 6.7).

b. Capability

While cross-linking technology is an existing capability, implementing this alternative will provide more flexibility in satellite communications (Capability Score; 2.0 and 2.0 and 3.0). This added flexibility to redirect communications paths via cross-links will result in a more capable architecture. Capability will also be dramatically improved by increased bandwidth if the cross links are established with lasers.

c. Risk

The technology risk for implementing either laser or RF cross-links is low. The technology is quite mature and is currently in use on some satellite systems (Risk Score: 5.0 and 5.0 and 3.0).

d. Cost

The Union of Concerned Scientists' Satellite Database was used to help complete the cost estimate for this alternative. After querying the database, we were able to determine that 250 satellites are currently being used to service the communications requirements for government and military applications. Our estimate was based on replacing each of these satellites with new ones containing cross-links. Based on a cost of $600 thousand per copy for one laser transmitter, the cost of implementing this alternative amounts to $150 million dollars (Cost Score: 4.0 and 4.0 and 4.0, Degree of Certainty: Medium and Low and Low).

Possible Setbacks (constraints / restraints)

There are no foreseeable setbacks to implementing this alternative.

6. Space Control Gaps

We identified three space control gaps from the requirements we established SS 3041. The Space control gaps were stealth capabilities for our satellites, enhanced satellite jamming capabilities and the ability to provide enemy satellites with undetectable false information.

A lack of stealth capabilities for our satellites in the future is an acceptable risk. It is an acceptable risk because our future architecture is designed to have the protection capabilities. Our counter ASAT capability will provide our satellites with a layer of protection. If our counter ASAT program does fail our future architecture includes increased launch capability, which will be able to replace on orbit assets in a timely manner.

The absence of enhanced satellite jamming capabilities of our enemy is also an acceptable risk. At the current pace of technology development, terrestrial jamming systems will continue to improve and will be able to meet our mission requirements. Currently we have platforms such as the EA 6B Prowler and Rubicon-I/II. These assets can provide monitoring of the electromagnetic spectrum and actively deny an adversary the use of radar and communications. New platforms, such as the EA-18 Growler, are being developed to continue this mission into the future.

The ability to provide enemy satellites with undetectable false information is also an acceptable risk for our future architecture. We identified this as a requirement for our future architecture as a means to achieve information superiority. Upon further research we found the military is actively pursuing several other means to achieve this goal. Information operations have become an extremely important aspect of military planning. Joint Publication 3-13 outlines the process by which US forces can achieve and maintain information superiority throughout the battle space. We do not need to rely on space assets to achieve information superiority.

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VI. IMPLEMENTATION

As stated before, Team A's tasks were to predict what the future NSSE environment would look like, identify what capability would be required to operate in that environment, and propose an architecture of solutions that would fill the gaps between the future required capability and current capabilities; all with the aim of providing unfettered access to any of those future capabilities across any combination of user and utility level. Team A's recommendation would be to sign on to invest almost $40 Billion in the final sixteen alternatives in order to ensure that all identified requirements are met and all risk related to the team's prediction of the 2025 environment would be accounted for. However, the reality of the situation is that there are many stakeholders that necessarily don't have an overall systemic view and are concerned with their particular mission area. The team also realized that, to some of the stakeholders in the decision process, the benefits of space are transparent. When the capability or product arrives, the stakeholders have no comprehension of where the product came from. For space to be truly responsive to its customers, they won't notice it until it goes away. It is hard to convince such a customer that spending the time and effort to secure space and make it responsive is important. The team believes that majority of the decision makers will not see, as Team A does, that not fully implementing ORS, will generate more unacceptable risk than perhaps diverting funds from development of newer conventional weapons or a necessary re-organization of the NSSE. Although the team would like to close with a list of 16 alternatives and be done, the IPT will try and provide a logical method of implementing the alternatives, and perhaps, ways to ensure that all of our suggestions will eventually be incorporated into the NSSE architecture.

As with all results, the number of interpretations of the data typically equals the number of individuals that examine the data. Also, lots of data doesn't necessarily mean lots of quality data. For this study, there were several weak points to the data collected based on ignorance of methods to collect data or lack of quality resources (e.g. cost, TRL). The analysis of each alternative against the four criteria not only served to help make the final architecture decision but was also used to help determine when, how and why to implement particular alternatives. In this analysis, the combined Responsiveness, Capability and Risk (RCR) was treated as one data point for each alternative and the cost of that alternative as another.

Appendix G shows some graphs of the data collected during this study. The first graph is a plot of cumulative RCR and cumulative cost data for the final sixteen alternatives. The plot shows a somewhat linear increase in RCR against an almost exponential increase in cost from least expensive to most expensive. The graph shows that, for a complete implementation of all sixteen alternatives, there is an approximate average of 45 points of RCR gained for every billion dollars spent, or 4.5 points of RCR for every one-hundred million spent.

The next graph is a plot of each alternative's RCR per one-hundred million dollar spent against the total estimated cost for each alternative. This graph is useful in that it readily identifies those alternatives that are a better investment for amount spent to total responsiveness gained. Of note, the Space Support Single Space Agency alternative produces almost 49 times the average of RCR per $100M spent. The graph also shows that the last five alternatives are all below the average of 4.5 points of RCR for every one-hundred million spent as derived from the first plot of data.

The final graph is perhaps the most useful for decision makers when analyzing which alternatives should get funded and which require more development and refinement before they can be considered for implementation. This graph shows cumulative and normalized RCR to $100M spent and cumulative and normalized cost as percentages. The graph also includes consideration to sensitivity analysis due to the low degree of certainty associated with a majority of the cost estimates in this study. The graph shows Y-Error bars that represent the change in data should the total costs be underestimated by 100% and overestimated by 50%. The sensitivity analysis shows that in all but the last five alternatives, no significant change in outcome would occur should the cost increase or decrease on the given scale.

From the analysis of these three graphs, Team A suggests the following three implementation schemes:

1. Minimum Cost Implementation:

   Implement the Space Support Single Space Agency Alternative only. This would provide the most responsiveness (219 RCR points or 45% of total) at the least amount of cost ($110M or 0.3% of total costs). Although this alternative is the cheapest and should

easily pass the rigorous acquisition process, it leaves a majority of the identified requirements for the 2025 environment unaccounted for.

2. Best Tradeoff Implementation:

Implement all but the last five alternatives. This implementation provides 98% of the total RCR available (approximately 1200 RCR points) for only 15% of the total estimated cost (approximately $6.2B). This implementation plan puts the architecture as close to the forecast required as possible while maintaining a realistic price tag. However, the final five alternatives should not be discarded but investigated further to reduce price and therefore increase the RCR to cost ratio. As time progresses, all the alternatives will be refined through the application of better technology and better cost estimates, therefore, the final five may eventually be more affordable and provide more responsiveness.

3. Complete Implementation:

Implement all sixteen alternatives for approximately 1800 RCR points at a cost of approximately $40B. This alternative will not only be the most expensive but will also be the hardest to sell to the stakeholders in the NSSE.

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VII. AREAS OF IMPROVEMENT AND FURTHER STUDY

1. Method of Evaluation:

Team A believes that each of the criteria it used to evaluate each alternative was sound and should be included in any future analysis of alternatives for space architecture alternatives. However, the team also believes that there was room for improvement for how each was applied and graded. For example, in both the responsiveness and capability criteria there was not allowance for a relative scale. Being able to evaluate and track the relative usefulness and capability between different alternatives may have led to a more subjective comparison and may have shortened the decision iteration cycle.

2. Technology Forecast:

Given the distant year of 2025 for final implementation, trying to forecast exactly what technology would be available proved extremely difficult. Also, the relative inexperience of the IPT compared to that of the professionals that would actually develop the ORS architecture lends an air of artificiality to the selected TRL for each alternative. Analysis should be conducted as to whether the reliance on open source material for data versus classified sources would have made a difference in assigned TRL. Finally, no consideration was given to how much funding exists for current research into each alternative area and how much effort is taking place in each area. This would have allowed for a relative weighting being applied to those technologies, that although relatively immature at the time of analysis were rapidly becoming mature and hence would have received a higher RCR score.

3. Cost Estimation:

As with Technology Forecast, the lack of projectable data, lack of experience and possibly the lack of classified information may have all led to inaccurate numbers and a lowered degree of certainty. However, by building in a +100% and -50% error into the final analysis, it was shown that there would be little to no change in our Team's recommendation should the actual cost prove to be different than the original analysis.

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APPENDIX A – ORS REQUIREMENTS FOR 2025

Space Control

Protection
- Enhanced satellite jamming capabilities
- Anti-ASAT capabilities against kinetic weapons
- Improved self-defense mechanisms for military satellites
- Anti-ASAT capabilities across the spectrum of ASAT weapons
- Stealth capabilities for our satellites

Prevention
- Enhanced anti-jamming capabilities
- Better encryption for our satellites

Negation
- Enhanced satellite jamming capabilities
- Anti-ASAT capabilities against kinetic weapons
- Anti-ASAT capabilities across the spectrum of ASAT weapons
- Capability to provide enemy satellites with undetectable false information

Surveillance
- A network of sensors capable of detecting movement and transmission from any satellite

Force Enhancement

Indications, Tracking, Warning, and Attack Assessment (ITW/AA)
- Threat warning and assessment all the way to ground level

Environmental Monitoring (EM)
- Integrated, real time weather [space and terrestrial] updates

Complete Integration with Terrestrial Systems
- Common Database and ubiquitous interoperability with U.S/Allied systems

Communications
- SATCOM bandwidth capable of handling surge requirements

Position, Navigation, and Timing (PNT)
- Improved anti-jam/jam detection capabilities

Intelligence, Surveillance, and Reconnaissance (ISR)

- Assured imagery for tactical requirements
- Persistent high-resolution imagery surveillance

Space Support

Space Lift

- Streamlined/minimized pre-pad & on-pad processing time
- Alternative launch options for broadened orbit choices and increased launch capacity
- Inexpensive, efficient, flexible lift vehicles

Launch On Demand

- A " ready-alert” capacity (satellites & boosters) to launch a replacement satellite, of each mission type (IMINT, SIGINT, COMM, etc), within 72 hours

Satellite Operations / Telemetry, Tracking, & Control (TT&C)

- Improved coordination and tasking of Intelligence/DoD satellite assets [ground]
- All future assets capable of communicating with each other, regardless of mission area [on-orbit]
- Capability to extend satellite service-life and upgrade/change mission capabilities [on-orbit]

Force Application

- Maintain ICBM capabilities
- Wide range of weaponry to be used from space against space targets on non-permanent basis
- Wide range of weaponry to be used from space against ground targets on permanent basis
- Capabilities for useful loads (troops, logistics, weapons) delivered across the globe in hours
- Joint/combined doctrine for use of weapons from space
- Joint targeting process that allows commanders at all levels to incorporate space force applications into fires planning

APPENDIX B – ORIGINAL SIXTY-ONE ORS ALTERNATIVES FOR 2025

Space Support (SS)

Space lift (SL)
SS.SL.1 Maintain current launch pad infrastructure (Cape/VAFB) – double work shifts; plug & play

- Decrease pre-pad and on-pad processing time-requirements by utilizing two work shifts vice one inside integration facilities
    - Decreases total processing time for Atlas from 60 to 30 days
    - Decreases total processing time for Delta from 24 to 12 days
- Utilize plug and play components

SS.SL.2 Modify current launch pad infrastructure (Cape/VAFB) – build additional HIFs & VIFs

- Build additional Horizontal Integration Facilities (HIF) (Delta)
    - Construct five-bay HIFs for each launch pad at each launch site (six total) to include three bays for processing and two bays for storage
    - Decreases on-pad time to 3 days or less
- Once the vehicle is integrated, a "transporter" will move the vehicle from the HIF/VIF to the actual launch pad for final processing/fueling (< 3 days)
- Build additional Vertical Integration Facilities (VIF) (Atlas)
        - Need more info on building VIFs
- Decrease pre-pad and on-pad processing time-requirements by utilizing two work shifts vice one inside integration facilities
- Utilize plug and play components

SS.SL.3 Build additional launch pads and increase infrastructure

- 1 per site to increase Cape to five and VAFB to four; 9 total pads vice 7
- Increases launch capacity from 18/yr to 23/yr for both sites

SS.SL.4 Utilize Sea Launch and Spaceports as additional launch options

- Sea Launch: Used to launch some NMM vehicles
- Spaceports: Likely only support smaller-sized vehicles
    - Currently 8 operating/planned US spaceports

SS.SL.5 Develop inexpensive, efficient, flexible lift vehicle(s) to launch smaller satellites

- Falcon, Spaceship 1, or Commercial space lift
  to reduce overall launch costs and provide increased access to space
  to improve cost-effectiveness and capitalize on technology developments

Launch On Demand / Reconstitution (LOD)
SS.LOD.1 Ready Alert within 72 Hours

- Satellites are already integrated, tested and stored in the HIF

- Utilize a plug-and-play payload and launch vehicle to enable periodic upgrades to stored spares or to trouble-shoot booster problems
- Backfill launched “ready-alert” satellite within 4 weeks
- Integrated booster/payload spare of each mission type stored at the contractor build site and shipped/ integrated/ stored within HIF

SS.LOD.2 Build-and-launch replacements in weeks/months
- Cookie-cutter satellite mission types to decrease procurement/ build times
- Plug-play payload design to allow for upgrades both on the ground and on-orbit by autonomous robotic vehicles
- Acquisition process done in advance
- On-pad efficiencies reduce time while maintaining lowest possible risk

SS.LOD.3 On-orbit spare(s) of each mission type

Satellite Operations / TT&C (SO)
SS.SO.1 Mobile Training Team
- NGA, in coordination w/the IC, establish a mobile training team to educate national asset users at all levels on product request procedures and tools

SS.SO.2 NTM Tasking Board
- Prioritizes satellite tasking both daily and long-term
- Rapid re-tasking - establish a Fusion Coordination Cell to monitor & assimilate real-time info from NTM and re-task assets as required to support both DoD & the IC “on-the-fly”

SS.SO.3 Single Space Agency
- Push decision down to the lowest level
- COC and decision-making flat and quick
- Coordination and tasking should happen in one location
- Joint Command (DoD, IC, Gov’t Agencies)
- NTM Tasking Board (prioritizes satellite tasking)
  - One overarching, joint-manned, tasking organization capable of making re-tasking decisions
  - Establish a Fusion Coordination Cell to monitor & assimilate real-time info from NTM and re-task assets as required to support both DoD & the IC “on-the-fly”
- Joint Space Acquisition Office (DoD, IC, Gov’t Agencies)

SS.SO.4 Enable all future on-orbit assets to crosslink
- All satellites include this capability in the design process starting in 2010

SS.SO.5 Develop and employ an on-orbit satellite servicing capability (robotics) to conduct routine servicing (fuel replenishment) and replacement/upgrades to satellite bus & payload

Force Application (FA)

FA.1 Maintain current ICBM inventory and "balanced response" policy

- Self explanatory

FA.2 Phase out current inventory of ICBMs when/if deterrence achieved by rapid reaction force capability

- Eventually replace "strategic reach" of ICBM with Rapid Reaction Force or Ballistic Conventional Weapon

FA.3 Develop non-permanent effects weapons

- Temporary effects such as dazzling, jamming, etc.

FA.4 Develop permanent effects weapons

- Lasting effects such as directed energy, kinetic kill, etc.

FA.5 Hyper-sonic vehicle that can carry troops, supplies, and weapons

- Ballistic trajectory vehicle deployable to any location worldwide in two hours or less.

FA.6 Space-based pre-positioning capability for supplies and weapons

FA.7 Develop Joint publication with input from all four services

FA.8 Develop separate targeting process for space delivered effects

FA.9 Integrate current joint fires targeting process for space delivered effects into processes

Force Enhancement (FE)

Indications, Tracking, Warning and Attack Assessment (IA)

FE.IA.1 Continue with incremental improvements to our current architecture

FE.IA.2 Create joint ventures with other countries and share costs and resources

- Stop doing ITW/AA alone. Work with our allies to meet this need. By combining assets and resources a better product can be produced for a lower cost.

Environmental Monitoring (E)

FE.E.1 Continue with incremental improvements to our current architecture

FE.E.2 Create joint ventures with other countries and share costs and resources

- Stop doing environmental monitoring alone. Work with allied countries and organizations to meet this need. By combining assets and resources a better product can be produced for a lower cost.

Complete Integration with Terrestrial Systems (CI)
FE.CI.1 Expand functionality of current information systems to include cross system sharing
- Slowly but surely make our current information systems interoperable. This would include compatible data formats, an accepted communication protocol, and policies for access.

FE.CI.2 Design, build and implement a new Integration Architecture
- Design, build and implement a new information system architecture to meet the data requirements of all parties that involved in ORS.

Communications (C)
FE.C.1 Continue with incremental improvements to our current orbital architecture (Military & Commercial)

FE.C.2 Develop, build and launch military owned and operated architecture
Stop purchasing communication capabilities from commercial companies. Develop and deploy a communications architecture that gives us complete ownership and control.

FE.C.3 Leverage the commercial market by deploying hosted payloads on future launches
- Place military communications payloads on commercial satellites (like leasing the space on the satellite). We would have complete control of the payload. In times of excess capability we could sell bandwidth to commercial users.

FE.C.4 Invest in and deploy high altitude airship platforms and payloads
- High-altitude long-loiter airships are currently in development and offer persist coverage of a given region. This capability offers a way to augment our current orbital communications systems.

Position, Navigation, and Timing (P)
FE.P.1 Augment current architecture with GPS Block III enhancements
- GPS Block III, when at Full Operational Capability (FOC), will provide several capabilities which will enhance anti-jamming capability.

FE.P.2 Ensure interoperability with all other major Navigation constellations
- Interoperability point is the same as that just made with GPS Block III

FE.P.3 Implement Inertial Navigation Capabilities to operate until GPS Signal re- established
- INS technologies are already being widely used in smart bombs. The idea here is to try to increase that capability to other non-weapon items to support continuous navigation (degraded) in the temporary absence of a reliable GPS signal.

Intelligence, Surveillance, Reconnaissance (I)
FE.I.1 Continue with incremental improvements to our current architecture

FE.I.2 Lower classification of images to ease distribution

- Quantum cryptography or other highly secure means of protecting and transmitting these images at a lower security level could be employed

FE.I.3 Add a secondary payload to each Iridium NEXT satellite to provide global EO coverage
- Iridium is currently looking for partners to launch secondary payloads on their new constellation of 66 LEO comms satellites called “Iridium NEXT.”

FE.I.4 Field a constellation of satellites in MEO to increase persistence
- Adaptive Optics and Segmented Mirrors are being used on NASA’s James Webb Space Telescope. If applied to an Earth orbiting EO satellite the technology could provide a much larger aperture with high resolution capable in a MEO. This would result in both more dwell time (= responsiveness) and great protection from an ASAT attack. (61m aperture = .1 m GSD from 10,000 km)

FE.I.5 Augment next generation of LEO EO satellites with high-altitude long-loiter airships
- High-altitude long-loiter airships are currently in development and offer persist coverage of a given region. This capability offers a way to augment our current orbital systems for a number of mission areas.

Space Control (SC)

Protection (P)
SC.P.1 Enhance satellite anti-jam capability

SC.P.2 Establish ASAT early warning cell
- Personnel and space surveillance assets dedicated to early warning against kinetic ASAT threats to friendly satellites

SC.P.3 Develop terrestrial based counter-ASAT weapons
- Terrestrial based counter-ASAT system will include both directed energy and kinetic weapons

SC.P.4 Develop space based counter-ASAT weapons
- System comprised of network of space based lasers and kinetic weapons

SC.P.5 Require additional shielding on future sats
- Will provide greater protection from space environment and EMP

SC.P.6 Develop maneuver on demand capability
- Maneuver on demand capability based on “orbital service station” concept

SC.P.7 Develop filters to protect optical/IR focal planes
- Filter/shutter will provide protection against laser dazzling

SC.P.8 Develop radar evasive shapes and materials for sats

- Adapt current stealth technology for operation on satellites

SC.P.9 Employ adaptive camouflage on sats
- Adaptive camouflage would provide visible stealth

Negation (N)
SC.N.1 Continue to develop mobile terrestrial jammers
- System will temporarily deny adversary use of communications satellites (within jammer footprint)

SC.N.2 Equip future sats with jammers
- On orbit jamming capability to temporarily deny use of communications satellites

SC.N.3 Develop terrestrial based ASAT weapons
- Terrestrial based counter-ASAT system will include both directed energy and kinetic weapons

SC.N.4 Develop space based ASAT weapons
- System comprised of network of space based lasers and kinetic weapons

SC.N.5 Develop maneuver on demand capability
- Maneuver on demand capability based on "orbital service station" concept

SC.N.6 Develop filters to protect optical/IR focal planes
- Filter/shutter will provide protection against laser dazzling

Surveillance (S)
SC.S.1 Continue use of terrestrial based surveillance telescopes and radars with incremental upgrades
- Network of telescopes and radars to visually track adversary's satellites from the ground

SC.S.2 Develop space based surveillance network (radar & optical)

SC.S.3 Add more electro-optical and radar sensors worldwide to minimize gaps in surveillance coverage

Prevention (P)
SC.PV.1 Require RF cross links on all future sats

SC.PV.2 Require laser cross links on all future sats
- Provides alternative to counter sat-to-sat RF interference; laser cross links have limited range (typically 40 km)

SC.PV.3 Require encryption on all military leased commercial SATCOM and imagery
- Prevent compromise of communications and satellite imagery from commercial satellites

APPENDIX C - RESPONSIVENESS SURVEY INSTRUCTIONS AND SAMPLE

Survey Instructions:

1. Review each JP 3-13 Mission Area alternative and, in your expert opinion, decide whether the alternative will provide any level of responsiveness to each level of user at each level of utility.
2. Place a check mark in the appropriate blank on the score sheet in and if the alternative will provide *any* level of increased responsiveness (only yes or no answer required; check if yes, leave blank if no)
3. The score sheet is laid out with a particular row being assigned to one alternative and the particular user/utility level assigned to the columns.
4. Total the number of check marks for each alternative and place the number in the "Total" Box at the end of the row.
5. Please contact Maj Senn (masenn@nps.edu) or
   LT Hansen (kmhansen@nps.edu) if you have questions.
6. Please complete the surveys by the 19 May.

1. Check each box that is responsive for a particular customer at a particular utility level 2. Add up number of checks for total.

	Space Support (SS) Space Lift (SL)									
	DoD			IC			Warfighter			Total
	Strat	Op.	Tact.	Strat.	Op.	Tact.	Strat.	Op.	Tact.	
SS.SL1										
SS.SL2										
SS.SL3										
SS.SL4										
SS.SL5										

	Space Support (SS) LOD / Reconstitution (LOD)									
	DoD			IC			Warfighter			Total
	Strat	Op.	Tact.	Strat.	Op.	Tact.	Strat.	Op.	Tact.	
SS.LOD.1										
SS.LOD.2										
SS.LOD.3										

	Space Support (SS) Satellite Operaions / TT&C (SO)									
	DoD			IC			Warfighter			Total
	Strat	Op.	Tact.	Strat.	Op.	Tact.	Strat.	Op.	Tact.	
SS.SO.1										
SS.SO.2										
SS.SO.3										
SS.SO.4										
SS.SO.5										

Figure 3: Sample Responsiveness Survey for Space Support

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APPENDIX D – RESPONSIVENESS, CAPABILITY, RISK AND COST SCORES

	Resp. (mean)	Capability	TRL Level	Risk Score	Cost	DOC	Cost Score
SS.SL.2	7.1	2	9	5	$102,000,000.00	High	4
SS.LOD.1	7.0	3	7	4	$4,000,000,000.00	Medium	2
SS.LOD.2	6.7	3	7	4	$0.00	High	5
SS.SO.1	6.6	3	9	5	$9,600,000.00	High	5
SS.SO.2	6.2	2	9	5	$3,000,000.00	Medium	5
SS.SO.3	7.8	3	9	5	$100,000,000.00	Low	4
SS.SO.4	6.7	3	5	3	$250,000,000.00	Low	4
FA.3	5.5	3	6	3	$3,200,000,000.00	Medium	2
FA.4	5.5	3	9	5	$4,700,000,000.00	Medium	2
FA.5	5.7	3	3	2	$240,000,000.00	Low	4
FE.IA.2	5.5	2	9	5	$550,000,000.00	Low	3
FE.E.2	6.1	2	9	5	$215,000,000.00	Low	4
FE.CI.1	7.3	2	6	3	$1,200,000,000.00	Low	3
FE.C.3	6.5	2	9	5	$1,200,000,000.00	Low	3
FE.C.4	6.2	3	5	3	$650,000,000.00	High	3
FE.P.3	5.4	2	9	5	$3,600,000,000.00	Medium	2
FE.I.3	6.9	3	8	4	$500,000,000.00	Low	3
FE.I.5	6.2	3	5	3	$450,000,000.00	Medium	4
SC.P.1	7.4	1	8	4	$13,900,000,000.00	Medium	1
SC.P.7	6.7	1	9	5	$750,000.00	Medium	5
SC.N.3	6.5	2	9	5	$4,250,000,000.00	High/Medium	2
SC.S.3	5.8	1	9	5	$396,000,000.00	High	4
SC.PV.1	7.0	2	9	5	$150,000,000.00	Medium	4
SC.PV.2	6.2	2	9	5	$150,000,000.00	Low	4

Table 5: Responsiveness, Capability, Risk and Cost Scores

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APPENDIX E – FINAL SIXTEEN ORS ALTERNATIVES FOR 2025

Space Support (3)

Space Launch (SS.SL.2): Modify current launch pad infrastructure (Cape/VAFB) – build additional HIFs

- Build additional Horizontal Integration Facilities (HIF) (Delta)
    - Construct five-bay HIFs for each launch pad at each launch site (six total) to include three bays for processing and two bays for storage
    - Decreases on-pad time to 3 days or less
        - Once the vehicle is integrated, a "transporter" will move the vehicle from the HIF to the actual launch pad for final processing/fueling (< 3 days)
- Decrease pre-pad and on-pad processing time-requirements by utilizing two work shifts vice one inside integration facilities
- Utilize plug and play components

Launch On Demand (SS.LOD.2H) Build-and-launch replacements in weeks for national systems and within 72 hours for small satellites such as TACSAT

- Cookie-cutter satellite mission types to decrease procurement/ build times
- Plug-play payload design to allow for upgrades both on the ground and on-orbit by autonomous robotic vehicles
- Acquisition process done in advance
- On-pad efficiencies reduce time while maintaining lowest possible risk

Satellite Operations / Tracking, Telemetry & Control (SS.SO.1, SS, SO, 2, SS.SO.3): Single Space Agency

- Push decision down to the lowest level
- COC and decision-making flat and quick
- Coordination and tasking should happen in one location
- Joint Command (DoD, IC, Gov't Agencies)
- NTM Tasking Board (prioritizes satellite tasking both daily and long-term)
    - One overarching, joint-manned, tasking organization capable of making re-tasking decisions
    - Rapid re-tasking: Establish a Fusion Coordination Cell to monitor & assimilate real-time info from NTM and re-task assets as required to support both DoD & the IC "on-the-fly"
- Joint Space Acquisition Office (DoD, IC, Gov't Agencies)
- Mobile Training Teams
    - NGA, in coordination with the IC, establish a mobile training team to educate national asset users at all levels on product request procedures and tools

Force Application (2)

Transport (FA.5): Hyper-sonic vehicle that can carry troops, supplies, and weapons

- Ballistic trajectory vehicle deployable to any location worldwide in two hours or less.

Space Weapons (FA.3, FA.4): As required, develop a combination of permanent and non-permanent effects space-based weapons against terrestrial targets

- Temporary effects include dazzling, jamming, etc…
- Lasting effects include directed energy, kinetic kill, etc…

Force Enhancement (7)

Indications, Tracking, Warning, and Attack Assessment (FE.IA.2): Create joint ventures with other countries and share costs and resources

- Stop doing *ITW/AA* alone. Work with our allies to meet this need. By combining assets and resources a better product can be produced for a lower cost.

Environmental Monitoring (FE.E.2): Create joint ventures with other countries and share costs and resources

- Stop doing *environmental monitoring* alone. Work with allied countries and organizations to meet this need. By combining assets and resources a better product can be produced for a lower cost.

Complete Integration with Terrestrial Systems (FE.CI.1): Expand functionality of current information systems to include cross system sharing (joint, interoperable protocol system)

- Slowly but surely make our current information systems interoperable. This would include compatible data formats, an accepted communication protocol, and policies for access.

Communications (FE.C.3): Leverage the commercial market by deploying hosted payloads on future launches

- Place military *communications* payloads on commercial satellites (like leasing the space on the satellite). We would have complete control of the payload. In times of excess capability we could sell bandwidth to commercial users.

Position, Navigation, and Timing (FE.P.3): Implement Inertial Navigation Capabilities to operate until GPS Signal re- established

- INS technologies are already being widely used in smart bombs. The idea here is to try to increase that capability to other non-weapon items to support continuous navigation (degraded) in the temporary absence of a reliable GPS signal.

Intelligence, Surveillance, and Reconnaissance (FE.I.3): Add a secondary payload to each Iridium NEXT satellite to provide persistent global *Electro-Optical (EO)* coverage

- Iridium is currently looking for partners to launch secondary payloads on their new constellation of 66 *LEO* communication satellites called "Iridium NEXT."

Tactical Communication & Imaging (FE.C.4, FE.I.5): Invest and deploy high-altitude long-loiter airships capable of providing communications and imagery to warfighters in the theater

- Augment the airships with current orbital communications systems and LEO EO satellites. Airships offer persistent coverage for a given region. Airships are currently in development.

Space Control (4)

Protection (SC.P.7, SC.P.1): Develop protection capability through the entire EM spectrum for all national space assets (includes protection against laser dazzling and communication jamming)

Negation (SC.N.3): Develop terrestrial-based counter ASAT system (both directed energy & kinetic weapons)

Surveillance (SC.S.3): Add more electro-optical and radar sensors worldwide to minimize gaps in surveillance coverage and to provide more accurate Space Situational Awareness (SSA)

Prevention (SC.PV.1, SC.PV.2, SS.SO.4): Shift to laser cross links on all future satellites while maintaining RF cross links on legacy systems

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APPENDIX F – OVERALL SCORES

Alternative	Overall Score (Eqn.2)	Cost
SS.SO.3	90.80	$100,000,000
SS.SO.1	82.17	$9,600,000
SS.LOD.1	81.42	$4,000,000,000
SS.SL.2	80.75	$102,000,000
SC.PV.1	80.18	$150,000,000
SS.LOD.2	79.12	$0
FE.I.3	78.42	$500,000,000
FE.C.3	76.73	$1,200,000,000
SC.N.3	76.15	$4,250,000,000
SS.SO.4	75.50	$250,000,000
FE.CI.1	75.24	$1,200,000,000
SC.P.1	74.57	$13,900,000,000
SC.PV.2	74.43	$150,000,000
FA.4	74.12	$4,700,000,000
SS.SO.2	73.85	$3,000,000
FE.E.2	73.28	$215,000,000
SC.P.7	73.01	$750,000
FE.C.4	72.05	$650,000,000
FE.I.5	72.05	$450,000,000
FE.IA.2	69.25	$550,000,000
FE.P.3	68.10	$3,600,000,000
FA.3	66.88	$3,200,000,000
SC.S.3	66.68	$396,000,000
FA.5	64.41	$240,000,000

Table 6: Overall Scores for Alternatives Included in Final Architecture

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APPENDIX G – DATA ANALYSIS

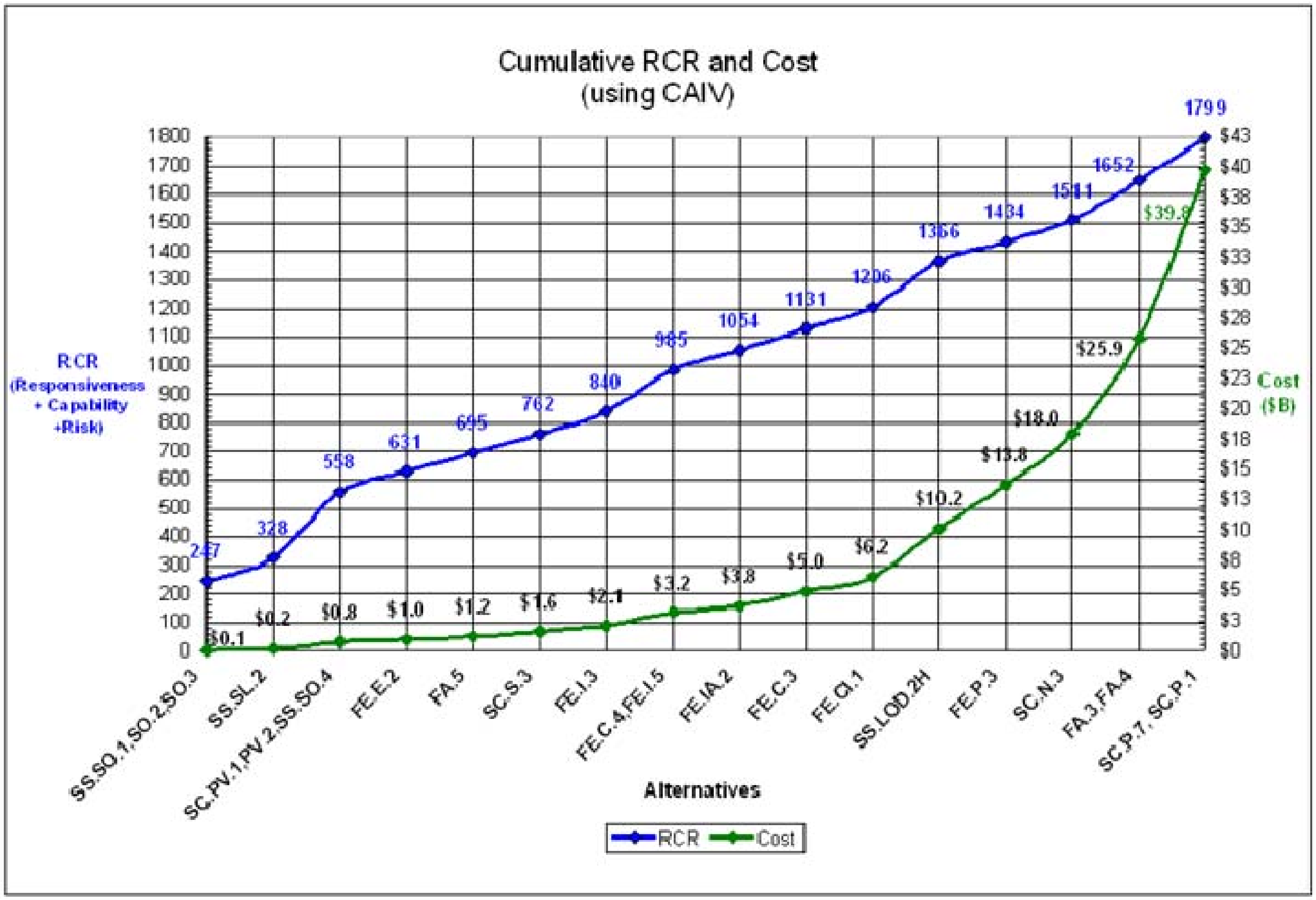

Figure 4: Cumulative RCR and Cost

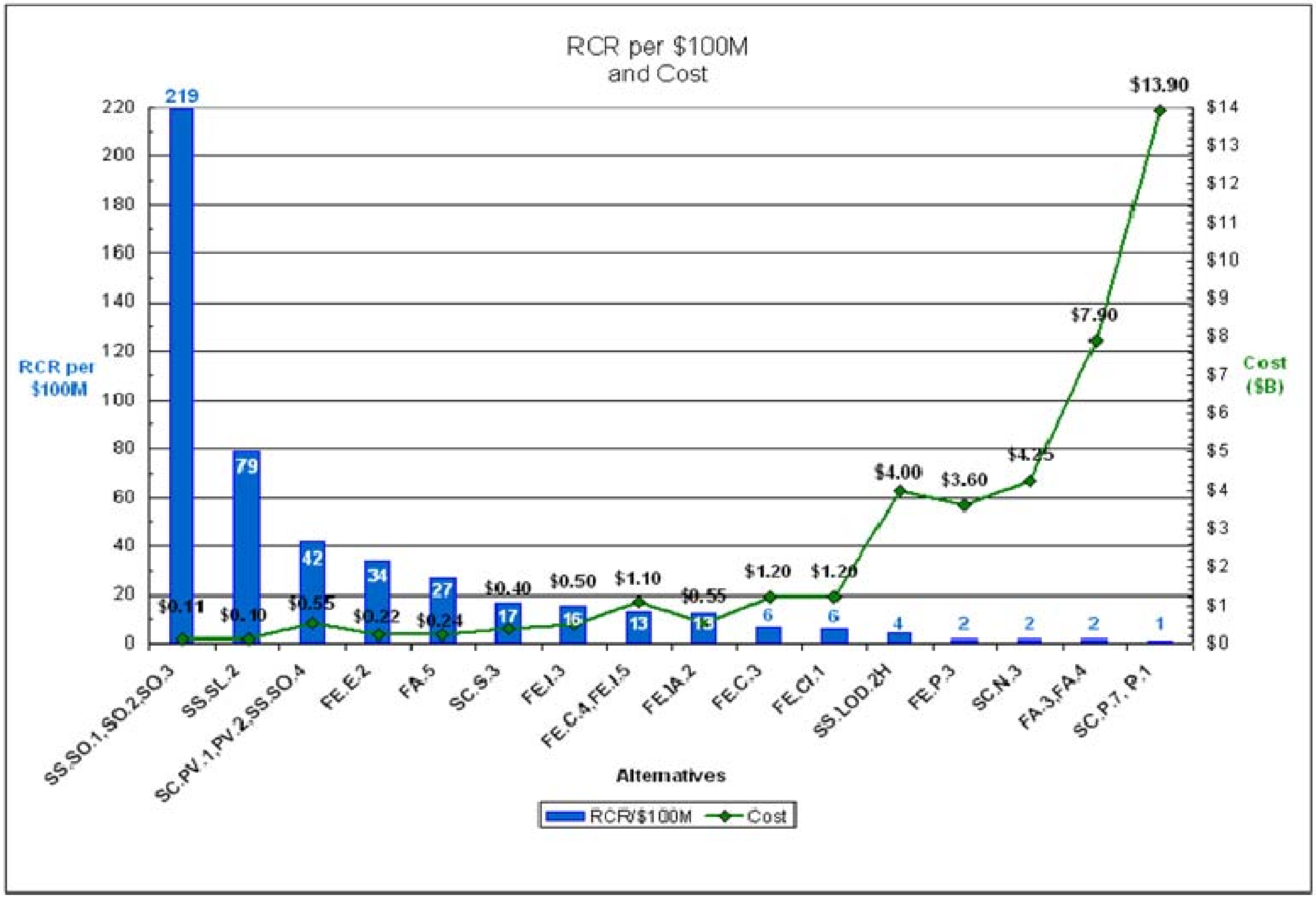

Figure 5: RCR per $100M and Cost

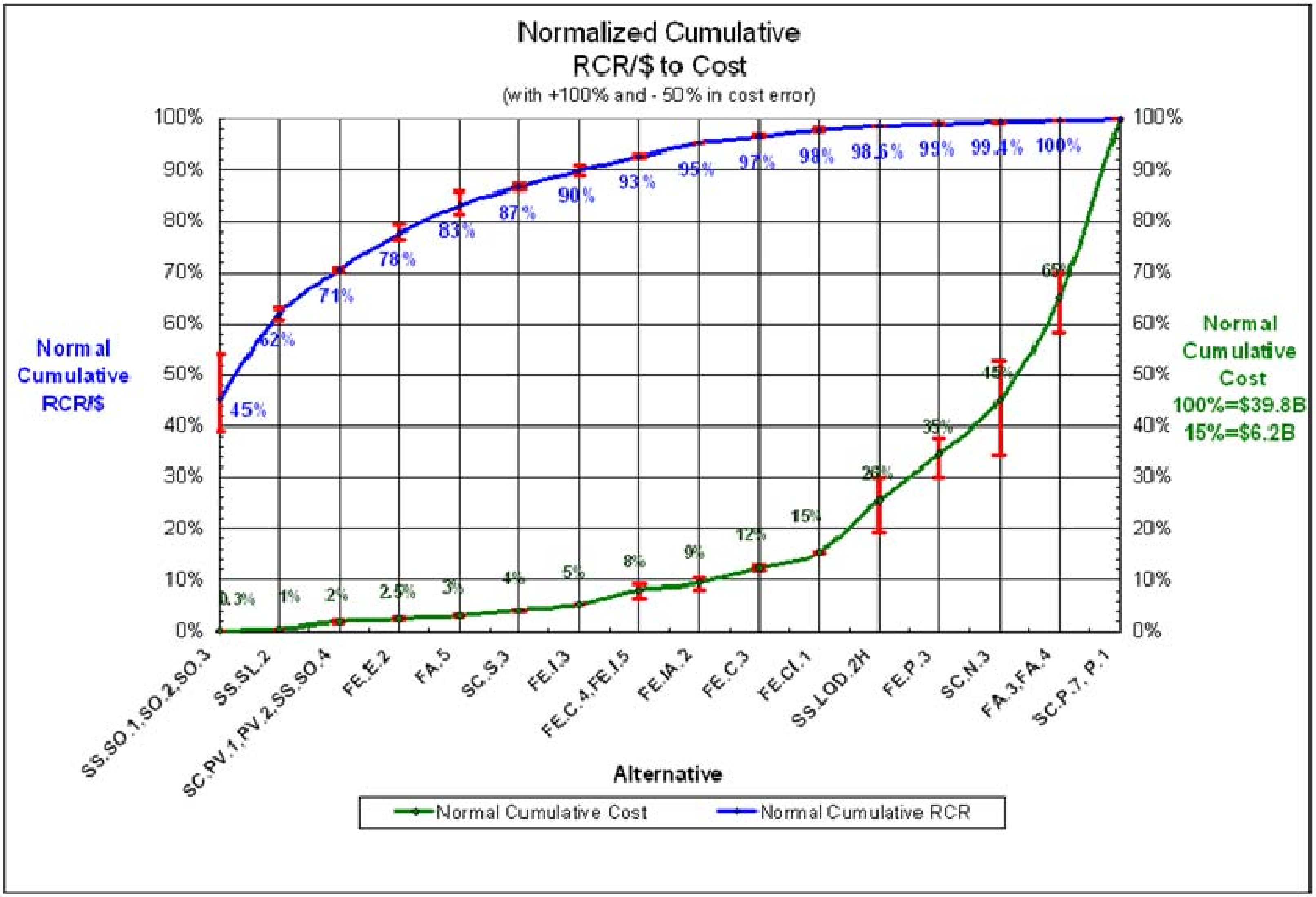

Figure 6: Normalized Cumulative RCR/$ and Cost

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